Heritage Science Austria

Final Report

Project (no.)	Heritage_2020-014_INDIGO
Project (title)	INventory and DIsseminate Graffiti along the dOnaukanal
Coordinator	Geert J. Verhoeven
Principal investigators	Geert J. Verhoeven (LBG) Norbert Pfeifer (TU Wien)
Host institutions	LBG - Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology TU Wien - Department of Geodesy and Geoinformation

Report period	01-09-2021 until 31-09-2023 (September 2023 is included because this report was finalised in October 2023 to incorporate INDIGO's second proceedings and links to the ARCHE data repository)

A. Content Report

Project INDIGO (IN-ventory and DI-sseminate G-raffiti along the d-O-naukanal) was a two-year project launched in September 2021 through funding from the Heritage Science Austria programme of the Austrian Academy of Sciences (ÖAW). This project wanted to push the status quo boundaries in inventorying and understanding extensive graffiti-scapes. INDIGO's project application stated that the project's main aim was to "build the basis to systematically document | disseminate | analyse almost 13 km of uninterrupted graffiti along Vienna's *Donaukanal* (Eng. Danube Canal)", the latter being a waterway in the city centre of Vienna.

Ideally, all graffiti recorded during those two years should be available and queryable via an online platform. Even though the INDIGO team has worked towards that goal during the two project years, creating this platform proved more demanding than initially thought. In practice, this meant that more basic research and software developments were needed. Since the quality of these fundaments was primordial, the coordinator decided in the second project year to invest more time in those aspects (also simultaneously publishing them) and less in producing records for what would have been a watered-down version of the envisioned graffiti dissemination platform. After all, what would a hastily constructed platform be worth if the basics would not allow for its optimal functioning? For example, the online platform should enable intricate queries such as:

When and where do political graffiti typically appear?
What are the main graffiti styles and colours used for those graffiti, and how long do they – on average – stay visible before they are (partly or entirely) covered?
What type of graffito commonly covers political messages?

To facilitate those queries, one needs specific 2D and 3D data structures, a way to track and reason with temporality, a thesaurus with well-defined terms and much contentual plus contextual metadata. Efforts to create such metadata schemes and a corpus of standard terminology are typically very time-intensive, low-visibility endeavours that come with little academic credit. Although this explains why they receive only

minimal focus in most academic heritage projects, INDIGO considered these efforts essential if the goal is to produce research data that can facilitate meaningful, varied and quantitative inquiry. In that way, INDIGO tried to generate 'smarter big data'.

By building all those theoretical, practical and logistical fundamentals, the INDIGO team developed more free software, initiated more collaborations, shared more datasets, and published more papers than was initially thought possible. This report hopefully reflects that. Section A1 explains all of INDIGO's research activities according to the WorkPackage (WP) structure mentioned in the project proposal, while Section A2 reflects on the project's two-year progress. Section A3 lists all the different kinds of publications (from peer-reviewed papers and thesauri to reference datasets and software code) resulting from this research. Sections A4 to A8 detail the resulting (inter)national collaborations, conferences attended and organised, presentations given and scholars invited. Section A9 illustrates the many facets of INDIGO's public dissemination, and Section A10 focuses on personal recruiting. Finally, Section A11 reports on INDIGO's entire organisational structure. An overview of the finances (Section B) and a duo-lingual summary (Section C) conclude this report.

Overall, project INDIGO aimed to deliver well-researched, high-quality and valuable outputs for the broader scientific graffiti and heritage community at the expense of achieving all goals in a mediocre manner. At the same time, the team went to great lengths to publish every aspect of the research (academically and for the general public) and be internationally very active. Combined, these aspects form the intended solid foundations upon which future academic graffiti projects can build. Since the project coordinator intends to find funding for a follow-up INDIGO 2.0 project, most outputs subject to versioning were denoted "version 1.0" (indicating that they result from what could now be called INDIGO 1.0).

1. Conducted and current research

To accomplish the project's aims, INDIGO was structured around five research pillars: 1) acquisition, 2) processing, 3) management, 4) dissemination and 5) analysis (graphical overview presented in Figure 1). Each pillar is covered by one or more Work Packages (WP). Since these 19 WPs form the actual management structure of project INDIGO, they are used below to detail all conducted research.
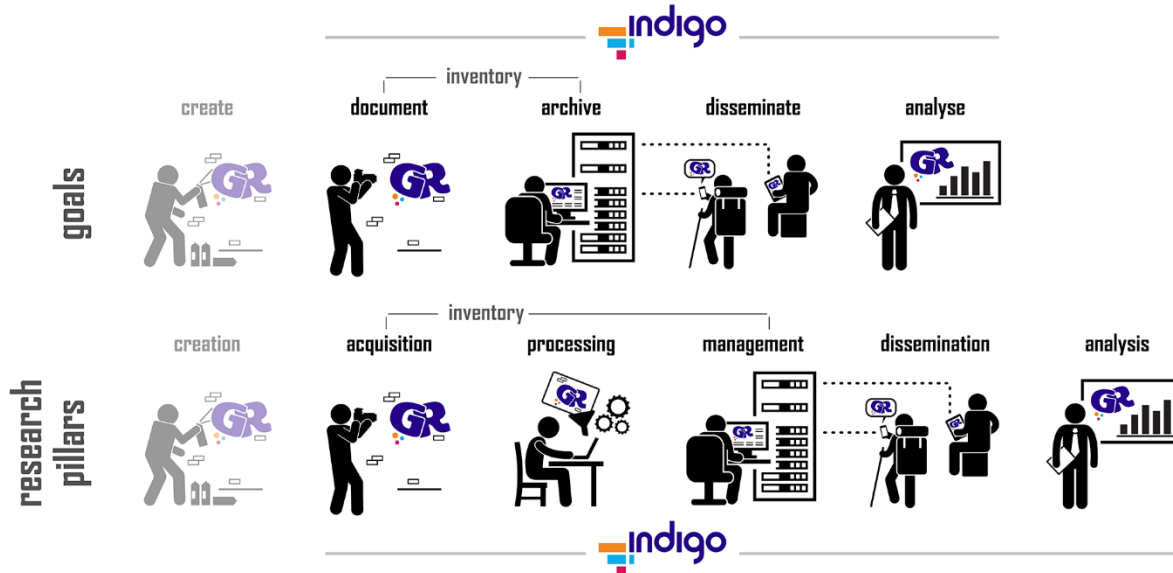

Figure 1 – A graphical overview of INDIGO's goals and research pillars. Although everything starts with producing a graffito, creating graffiti fell outside the scope of project INDIGO.

WP 1 – Management

Project management concerns the management of human resources as well as project data. Since the former will be covered as "organisational work" in the predefined Section A11, this section solely deals with the IT infrastructure and data structure INDIGO has set up to manage all project data.

INDIGO is a 'big data' project; it is a project in which one no longer counts in tens of gigabytes but in tens of terabytes (and that is only considering the unprocessed input data). Such increased data gathering brings considerably more responsibility. That is why, from the start, much thought was given to how and where data should be stored, named, backed up, and made available. The implemented system has rules on three different levels. Each level – computer, folder, and file – is detailed below.

Computer level

Project INDIGO bought two high-performing PCs, one for each host institution (Figure 2, [A] and [B]). In addition, existing computers were expanded with large-capacity hard disks (HDDs). At the centre of INDIGO's computer network is a workstation (indicated with [0] in Figure 2) with 54 TB of storage space. On this PC, all INDIGO data were accumulated and managed. The bulk of those data consisted of digital photographs, of which circa 100 GB got collected per week mainly by photographer Stefan Wogrin from INDIGO's partner organisation SprayCity. Since Stefan did not share an office in the building where the workstation was located, an online solution had to be established. Via a two-user Sync.com account with unlimited storage, data collected by Stefan were uploaded from his home computer (Figure 2, [C]) to Sync.com's cloud service (Figure 2, [3]) and automatically synchronised with INDIGO's central workstation. In that way, the team avoided a weekly physical transfer of a hard drive, thus saving precious time. This

two-way synchronisation worked with a temporary folder on Stefan's computer, Sync.com, and the workstation. As soon as Stefan's new data were integrated into the workstation's data structure and mirrored onto two external hard disks (see later), the temporary folder got deleted from the workstation, and sync.com removed it from Stefan's PC as well (who at that moment knew the data were safely stored).
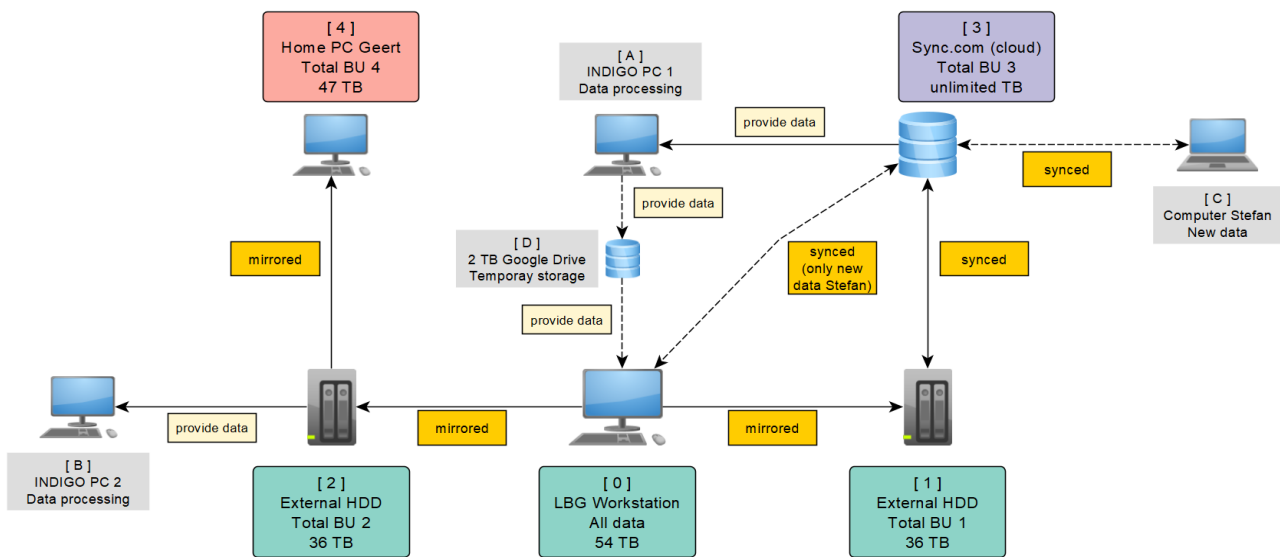

Figure 2 – Storage of INDIGO's reserach data.

Several times per day, all INDIGO data were mirrored from the workstation onto two 36 TB external hard disks ([1] and [2] in Figure 2). The capacity of those HDDs proved just sufficient at the end of INDIGO. This mirroring operation was essential to preserve data integrity on the workstation. On the workstation, all data were managed (i.e., structured, deleted, renamed); a syncing operation with other drives could potentially lead to unwanted effects if something happened on those drives. External HDD [1] was continuously synced with Sync.com, so at all times, a copy of INDIGO's data was available in the cloud. In that way, data could easily be shared with the TU Wien for processing on INDIGO PC 1 (Figure 2, [A]). Ideally, the connection between HDD [1] and Sync.com would perform a mirroring operation, but that was not supported. However, any failed syncing with the cloud service maximally affected the external HDD [1] and never reached the workstation. Since Sync.com provides end-to-end zero-knowledge encryption, their staff cannot open INDIGO's data without passing a two-level verification. That is why the service was independently reviewed as the most secure Cloud Storage solution to date. Finally, the project coordinator's home PC [Figure 2, [4]] also stored a copy of all data, achieved via a mirroring operation of External HDD [2] every weekend. HDD [2] also provided data to INDIGO PC 2 (Figure 2, [B]), which complemented the workstation in data processing. Processed data from INDIGO PC [2] reached the workstation via smaller external hard drives (not depicted in Figure 2) or via Google Drive for INDIGO PC 1 (Figure 2, [D]). INDIGO purchased 2 TB of Google Drive space to allow for smaller data transfers within the team (which was a cheaper solution than having additional user accounts for Sync.com). All the syncing and mirroring operations occurred automatically via profiles configured in the SyncBackPro software.

In that way, all INDIGO data were always available on five data carriers (the Workstation [1] and Total Back-Ups [1] to [4]) spread over three physical locations, indicated by the light red, green and purple labels in Figure 2.

Folder level

To distinguish the names of files and folders, folders have the first letter of each word capitalised – a naming convention called **PascalCase** – while files use **camelCase**. At the highest level, all INDIGO data are divided

into Primary and Supplementary (see Figure 3). Since photographs constitute INDIGO's core input and output, they were needed throughout multiple WPs. It thus seemed best to keep all imagery and image-related data (like spectrometer files and GNSS or Global Navigation Satellite System receiver log files with image positions) together. The **Primary** directory is divided into three subdirectories that – in combination – reflect the goal of INDIGO: acquiring graffiti data and processing those into colour-corrected orthophotographs, textures and meshes (see Figure 3). The **01-Input** folder thus contains all data that serve as input to obtain these deliverables (stored in **03-Output**). The **02-Processing** folder stores all intermediate products generated while turning input into output.

The 01-Input directory holds three directories representing the main data categories; each is subdivided into a folder per acquisition device (e.g., **GoProHERO10Black-A** or **NikonZ7ii-B** for ImageData; see Figure 3). 02-Processing features a folder per processing step (e.g., **01-Masking**, **02-CamerOrientation**) and 03-Output per data product type (e.g., **01-ColourimetricPhotos**, **03-Meshes**). In the instruments folder, **A** and **B** were used to separate different devices from the same type (bought to enable independent data acquisition by two photographers). A two-digit number prefix (e.g., **01**, **02**) means that the order of specific folders or subfolders mattered. A **04-Sandbox** folder stored files needed for coding or other experiments.

The **Supplementary** folder was not called **Secondary**, as the residing files are equally important. The Supplementary directory counts 19 subfolders with names corresponding to the different WPs (see Figure 3). These folders hold spreadsheets, PDFs of papers, literature databases, contracts, code, email lists, symposium plans, flyer designs, logos, and Newsletters. For instance, the thesaurus (see Section A1-WP13) resides in the **WP13-Thesaurus** folder. The thesaurus' final version is used as input for the spatial database and to tag metadata to the original graffiti photographs. Similarly, all other data in the different WP folders supplement (or report on) the primary data in one way or another.
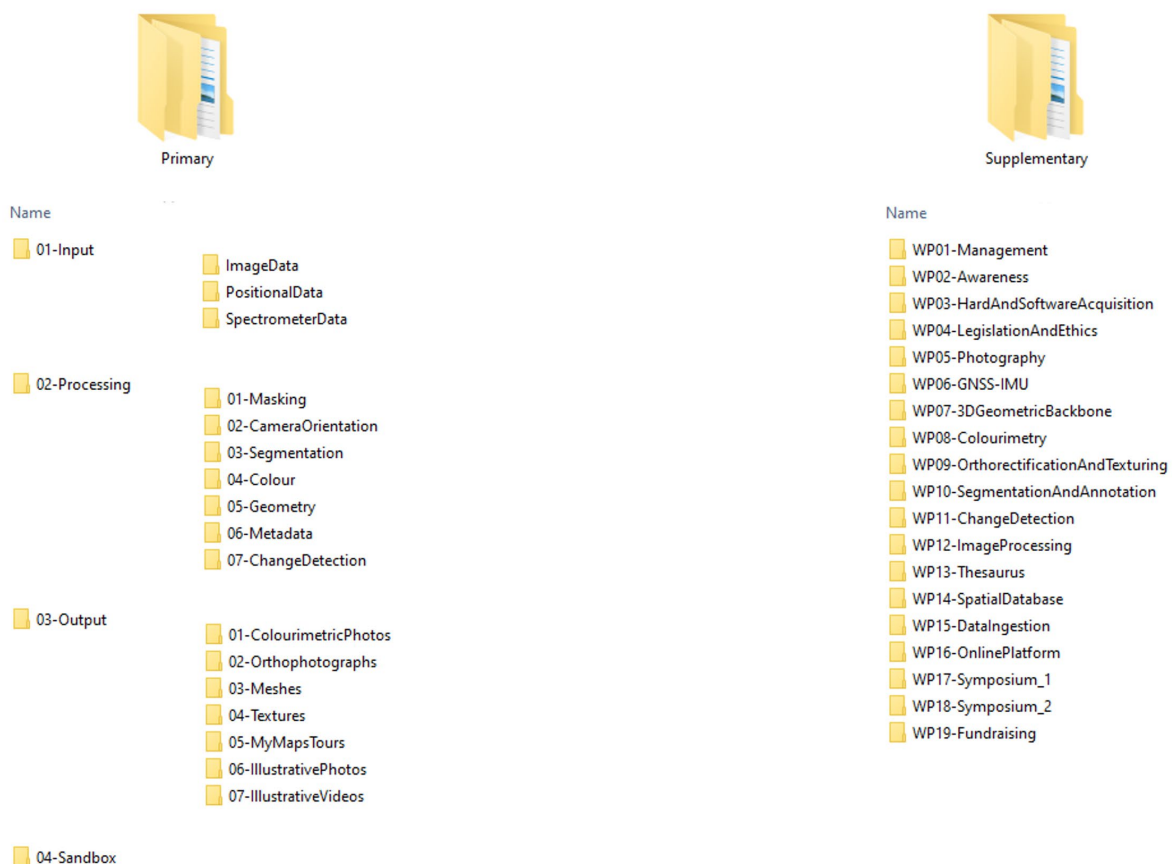

Figure 3 – INDIGO's data structure divides data between Primary and Supplementary.

This division also makes sense from a data dissemination point of view. INDIGO shares all its input data and final products freely online. Because the data in Primary typically do not need versioning – and because they are the core data and data products of INDIGO – they are stored in ARCHE, the certified repository of the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH; see also SectionA1-WP15). Over time, all primary INDIGO input data will be downloadable here: https://hdl.handle.net/21.11115/0000-0011-0DC7-F. Currently (October 2023), data cleaning and ingestion in ARCHE is ongoing. Due to the massive dataset size and the metadata that will be provided for (and, where applicable, also embedded within) each file, the finalisation of this process is foreseen around the end of December 2023.

Besides the input data, ARCHE should also disseminate INDIGO's output while the "processing" files are not archived. However, INDIGO's currently finalised products are situated almost exclusively in the Supplementary directory, so there was no need to store the 03-Output folder in ARCHE yet. However, this will certainly take place if renewed funding would allow for INDIGO 2.0 (as that project would leverage all foundational work of INDIGO 1.0 – see throughout this report).

All WP-specific deliverables are disseminated via platforms tailored to that particular output. For instance, code lives on GitHub, publications on Zenodo, the literature database on Zotero's platform, and videos on YouTube. Section A3 provides all the details on these varying academic outputs.

File level

It is never straightforward to consistently name a wide variety of files due to the vast number of possible file types and their purpose. Usually, user-friendly filenames resort to mnemonic values like "orthophoto" or "Nikon D750" to convey something about the file's content. However, such naming schemes typically overload the name with too many metadata values (a date, a value, the author(s), maybe a location etc.), which can violate the principles of abstraction and modular design. For computers, file names act as unique references, so having a long series of numbers like 78506ae9-af66-41ec-9453-55b5dc66f8c2 would be a much better, almost universally unique solution. Such pure names are ideal for databases, but nonsensical to humans. Since the requirements for sound but user-friendly file names create tensions between the demands for their uniqueness and resolvability versus the need to be consistent (e.g., CAPITAL or small letters, camelCase or PascalCase) and easy to generate (often using easy-to-remember non-technical values like names of instruments, persons or places), INDIGO established a human-understandable as well as a machine-processable unique identifier for every digital resource (at least those in the Primary directory). This idea resembles how account names relate to specific account numbers. INDIGO's strategy for this combined human- and machine-oriented identifier tries to solve the file naming tensions mentioned above.

However, having and tracking Universal Unique IDentifiers (UUIDs) for every file is hard without a proper Digital Asset Management system (DAM). That is why all INDIGO input data were managed in IMatch, a professional DAM built on top of Exiftool by Phil Harvey, the Swiss Army knife (and only truly reliable tool) for metadata manipulation of files in general and photographs specifically. IMatch runs on the Workstation ([0] in Figure 2), forming the central point of INDIGO's resource management. IMatch leverages Adobe's XMP namespace for Media Management to generate and track all these UUIDs.

Using IMatch or other renaming tools like Photo Mechanic Plus, files also received a human-oriented file name. Files in the 01-Input directory always consist of four parts separated by underscores and following this pattern: INDIGO_year-month-day_instrumentName_4DigitSequentialNumber. For instance, a photo could be named: INDIGO_2021-10-30_Z7ii-A_0017:

- INDIGO indicates the project name, making the data stand out from other projects.

- For dates, the [ISO 8601 format](#) is used: This standard stipulates the use of dates like YYYY-MM-DD, where YYYY is the year in the usual Gregorian calendar, MM is the month of the year between 01 (January) and 12 (December), and DD is the day of the month between 01 and 31. For example, the fourth day of February in 2015 becomes 2015-02-04. There is also a version without hyphens possible (i.e., YYYMMDD) if the compactness of the representation is more important than human readability. However, hyphens are preferred because they make the dates more human-friendly. One advantage of this system is that folders are always ordered chronologically.
- The instrument name omits the brand and only uses the type. For instance, the Nikon D750 camera is indicated as D750, while C7000 denotes the Sekonic C-7000 SPECTROMASTER spectrometer. For the Nikon Z7 II, we used Z7ii to avoid confusion between capital I (from Ingrid) and small case l (from lion). As mentioned, A and B were used to distinguish the two Nikon Z7 ii cameras or the different C7000 spectrometers used within INDIGO.
- The four-digit sequential number allowed one to take up to 9999 photographs daily. The maximum number of image files ever recorded in one day was 6931. Most photo acquisitions only created one GNSS log file, so these seldom reach numbers higher than 0001.

However, not all files are data input files, so deviations of this naming pattern were needed. Overall – and in addition to the conventions above – the INDIGO team tried to ensure that file names:

- did not use spaces or special characters
- were not longer than necessary (which was made possible via codes and acronyms)
- used underscores to separate different semantic parts
- used camelCase (in contrast to PascalCase for folders)
- used leading zeroes for sequential numbering.

These conventions were fixed during the second project month after the project coordinator proposed various naming options to five collaborators (see Figure 4). It is important to note that none of the proposals would cause problems in the spatial database OpenAtlas (see Section A1-[WP14](#)) and the data repository ARCHE (see Section A1-[WP15](#)).
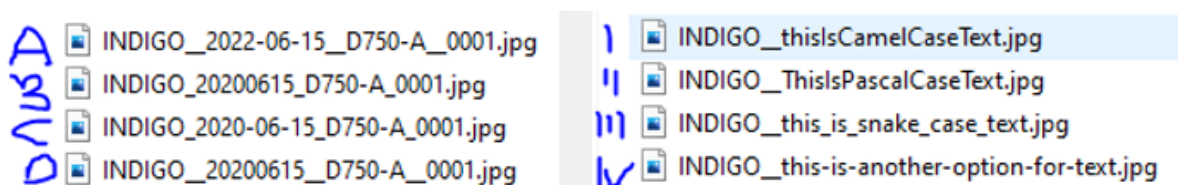
Martina	Alex	Seta	Benjamin	Jona	Geert
C	C	B	C (or B)	B (or C)	A
I		II	I	I	III or IV (or I)

Figure 4 – The different naming schemes proposed at the start of INDIGO. Finally, C and I were considered the winners.

WP 2 – Awareness

INDIGO dealt with multi-coloured content, often created by people referring to themselves as artists. That is why the graphical work always received the necessary attention. INDIGO's logo was designed to express simplicity and harmony; the logo's four-colour palette (see Figure 5) was also applied in nearly every piece of graphical project work: the website, illustrations, maps, logos of software and symposium, business cards, and posters.

font

Sans Sara, a balanced and simplified sans-serif letterform the lower-case, Bauhaus-inspired writing is matched in style by harmonious geometric shapes in vibrant colours

shapes

four *rectangles*, primary and familiar shapes to match the simplicity of the abstract typography their rigid arrangement symbolises the vibrant graffiti panels (pink and orange) that border the Danube Canal (in cyan) the elongated negative space vertically created by the left and right logo elements suggests one of several Canal bridges

colours

four vibrant paints to reflect graffiti's colourful character
indigo | sRGB 39   0 137 | CIELAB$_{D50}$ 15 45 -66 | Pantone 2735 C
orange | sRGB 241 136 31 | CIELAB$_{D50}$ 67 36 68 | Pantone 715 C
cyan | sRGB 13 172 229 | CIELAB$_{D50}$ 65 -22 -40 | Pantone 2995 C
pink | sRGB 210 20 92 | CIELAB$_{D50}$ 46 70 13 | Pantone 214 C

Figure 5 – The explanation of INDIGO's project logo and a technical description of the colour palette used.

Social media like Instagram and, to a lesser extent, Twitter were also important for INDIGO because they established the necessary engagement with the local graffiti community. INDIGO's social media strategies are detailed in Section A9.

Besides the usual public dissemination via a website (see Section A9) or YouTube channel, and academic dissemination through papers and software code (Section A3), symposia (Section A6), and presentations (Section A7), INDIGO also spread project awareness via the graffiti tours and workshops organised by Spraycity. Spraycity – in the person of Stefan Wogrin – established the necessary link between the academic and non-academic graffiti communities; Stefan also organised graffiti tours and workshops as alternative team-building events. During these events, Stefan raised awareness for project INDIGO. This resulted in a broad acceptance of the project within the local graffiti community, and sometimes even in surprising dissemination results. For instance, the Levin Statzer Foundation organised boat tours in September and October 2022 along the graffiti-scape of the Donaukanal. During these tours, project INDIGO and its goals were mentioned as well. Finally, INDIGO also got coverage via podcasts, written press (see Figure 6) and various blog posts (all detailed in Section A9).

Die Presse SAMSTAG, 16. JULI 2022

WISSEN & INNOVATION **W3**

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

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

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-

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.

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.

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 Far-

ben 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 Hundertwasserhaus 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 Universität 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.

Figure 6 – INDIGO press coverage in the Austrian newspaper *Die Presse* on the 16th of July 2022.

Raising this kind of awareness was considered necessary for a potential follow-up project. The effect of all the dissemination channels is that right now (October 2023), the project coordinator regularly receives invitations for workshops and lectures on graffiti.

Initially, INDIGO also wanted to create flyers and spray QR codes along the Donaukanal. Both would link to an online form to report new graffiti. However, a meeting with a spokesperson of the City of Vienna (which prefers to be anonymous) clarified that the QR code idea would only be acceptable on the < 300 m of legal graffiti walls. But the density of new graffiti appearing on these walls would mean that INDIGO's QR codes would likely be covered within a day. Combined with the limited stretch of surfaces on which these codes could find a place, the decision was taken to no longer pursue the QR idea. INDIGO-specific flyers were never created, either. First, Stefan Wogrin's workshops were a very effective means to 'spread the word'. Second, the project photographers who visited the Donaukanal frequently had business cards with personalised QR codes linked to the project website and its online reporting form (Figure 7). These business cards were considered a more compact replacement for the initial flyer idea.

Figure 7 – The front (on the left) and back (on the right) of Jona Schlegel's INDIGO business card. The QR codes are personalised and link to the general website and the online reporting form.

WP 3 – Hard- and software acquisition

During the first project months, considerable time was invested into researching and purchasing the most appropriate hard- and software at the best possible price. The intended products (i.e., those mentioned in the project proposal) were purchased in most cases. We only deviated in a few cases from the initial plan because more recent (or better value) solutions became available, or because the envisioned research strategy changed slightly. For instance, instead of two portable X-Rite Ci60 spectrophotometers, a more accurate Konica Minolta CM-26d was purchased. Initially, one of the intended instruments would have been sent to Spain, facilitating Adolfo Molada-Tebar to acquire the necessary data for his colourimetric developments. However, Adolfo could use a Spanish instrument that was at least as accurate as the X-Rite Ci60, so purchasing and operating a more accurate device in Vienna made sense. This instrument was important to develop the colourimetric workflow (see Section A1-WP 8).

In the second project year, hard- and software purchases drastically dropped. The team only purchased a few large hard drives and a handful of smaller licenses for software packages (like Google Drive and IMatch, or software to generate QR codes and optimise the sound of the goINDIGO 20023 symposium recordings). INDIGO had deliberately not spent the entire camera and lens budget. It soon became apparent that only two cameras and lens sets were needed instead of the anticipated three sets. The plan was to use the remaining money to counter hardware failures or damage. Due to the intensity of INDIGO's photographic activities, these were not unlikely. Despite the large number of photographs acquired by both cameras (circa 67k and 103k photos for cameras A and B, respectively), the photographic equipment stayed in perfect condition until the project's end. Only one Solmeta GMAX GNSS (Global Navigation Satellite System) receiver had to be replaced since its connection to the camera broke.

WP 4 – Legislation and ethics

This WP looked at the complex problem of image copyright and all aspects concerning legal data sharing. Workshops on these topics were attended, and various people consulted. Many of them found INDIGO an interesting case, but in the end, nobody could help us further. We also invited Enrico Bonadio – lawyer and author of all major graffiti copyright books – to the goINDIGO 2022 symposium to discuss this issue. Mister Bonadio stressed the variability and regionality of the law on this topic. So, the matter seemed to be highly complicated. After much research, INDIGO adopted the "In Copyright" statement for all photographs. This

statement from rightsstatements.org clarifies that each photograph "is protected by copyright and/or related rights. You are free to use this Item in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s)."

Because a photograph from a graffito has two copyrights (one held by the graffito creator and one by the photographer), the "In Copyright" statement is safe. Due to their general anonymity, INDIGO cannot contact every graffiti creator to clear their copyright. The "In Copyright" statement covers this situation because it notices that the user "may need to obtain other permissions for your intended use. For example, other rights such as publicity, privacy or moral rights may limit how you may use the material."

This copyright statement and all other license-related info (such as the creator and his/her identity, the official copyright owners and the copyright licensors) are stored within the IPTC ([International Press Telecommunications Council](#)) metadata section of every INDIGO photograph. Table 1 lists all rights-related IPTC metadata stored in each photo.

Table 1 – The rights-related values embedded in every INDIGO photo via IPTC metadata fields.

IPTC field	Value(s)	
Creator	Name of the photographer: Jona Schlegel | Geert J. Verhoeven | Stefan Wogrin	
Creator's Job Title	project INDIGO coordinator | project INDIGO collaborator	
Creator Contact Info	info@projectindigo.eu, gverhoev@gmail.com	
Copyright	© 2023. This work has an In Copyright license.	
Credit	project INDIGO [image] and graffiti creator(s) [content]	
Source	Ludwig Boltzmann Gesellschaft, TU Wien, anonymous graffiti creator(s)	
Copyright URL	https://rightsstatements.org/page/InC/1.0/	
Rights Usage Terms	This Item is protected by copyright and/or related rights. You are free to use this Item in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s). NOTICES - Unless expressly stated otherwise, the organisation that has made this Item available makes no warranties about the Item and cannot guarantee the accuracy of this Rights Statement. You are responsible for your own use. - You may find additional information about the copyright status of the Item on the website of the organisation that has made the Item available. - You may need to obtain other permissions for your intended use. For example, other rights such as publicity, privacy or moral rights may limit how you may use the material.	
Image Creator	**Name**	**Identifier**
	Geert J. Verhoeven (or another creator)	https://orcid.org/0000-0003-4825-9604
Copyright Owner	**Name**	**Identifier**
	Ludwig Boltzmann Gesellschaft TU Wien anonymous graffiti creator(s)	https://d-nb.info/gnd/1024204324 https://d-nb.info/gnd/55426-1
Licensor	**Name**	**Identifier**
	Ludwig Boltzmann Gesellschaft TU Wien	https://d-nb.info/gnd/1024204324 https://d-nb.info/gnd/55426-1

Since the beginning of INDIGO, it became clear that it would be crucial to consider and address moral and ethical questions (e.g., how to deal with hateful, subversive, potentially illegal or other sensitive content). As a result, WP 4 got extended to "legislation and ethics" in the first project months. INDIGO consulted TU Wien's research ethics coordination for counselling. Initial discussions led to a meeting between INDIGO project members and the Pilot Research Ethics Committee ([Pilot REC](#)). In this meeting, the project's ethical dimensions, and potential strategies to tackle them, were confidentially discussed. The conclusions drawn from this gathering served as a basis to address ethical responsibilities throughout the project. The entire statement can be found [here](#).

WP 5 – Photography

Taking photographs was one of the main activities within INDIGO. The original project plan mentioned four so-called 'total coverage' surveys besides weekly or bi-weekly 'follow-up' photography tours. Let us start with the latter.

During the entire project period, one of the three photographers documented new graffiti at least once per week. These photographers had a pool of various hardware available: two identical imaging systems, two ColorChecker Passport Photo 2 colour reference targets by X-Rite (now produced by Calibrite), two Solmeta GMAX GNSS (Global Navigation Satellite System) receivers, two Sekonic C-7000 SPECTROMASTER spectrometers and two Samsung Galaxy Tab A7 Lite tablets (see Figure 8). All devices of the same type were labelled "A" and "B" to distinguish them. Device B was always set up identically to device A. For example, the tablets ran the same apps, and all settings of both spectrometers were identical.

INDIGO relied on two Nikon NIKKOR Z 20mm f/1.8 S lenses paired with a full-frame mirrorless Nikon Z7 ii camera generating 45-megapixel photos. The Solmeta GNSS receiver was attached to the camera's hot shoe and directly wrote geographical coordinates into the photo's Exif metadata. Both cameras featured the same settings. This enforced identical results (from a technical point of view) across imaging systems and ensured that the camera-related photo properties were appropriate for INDIGO's colourimetric and geometric processing pipelines (detailed in WP 8 and WP 9, respectively).
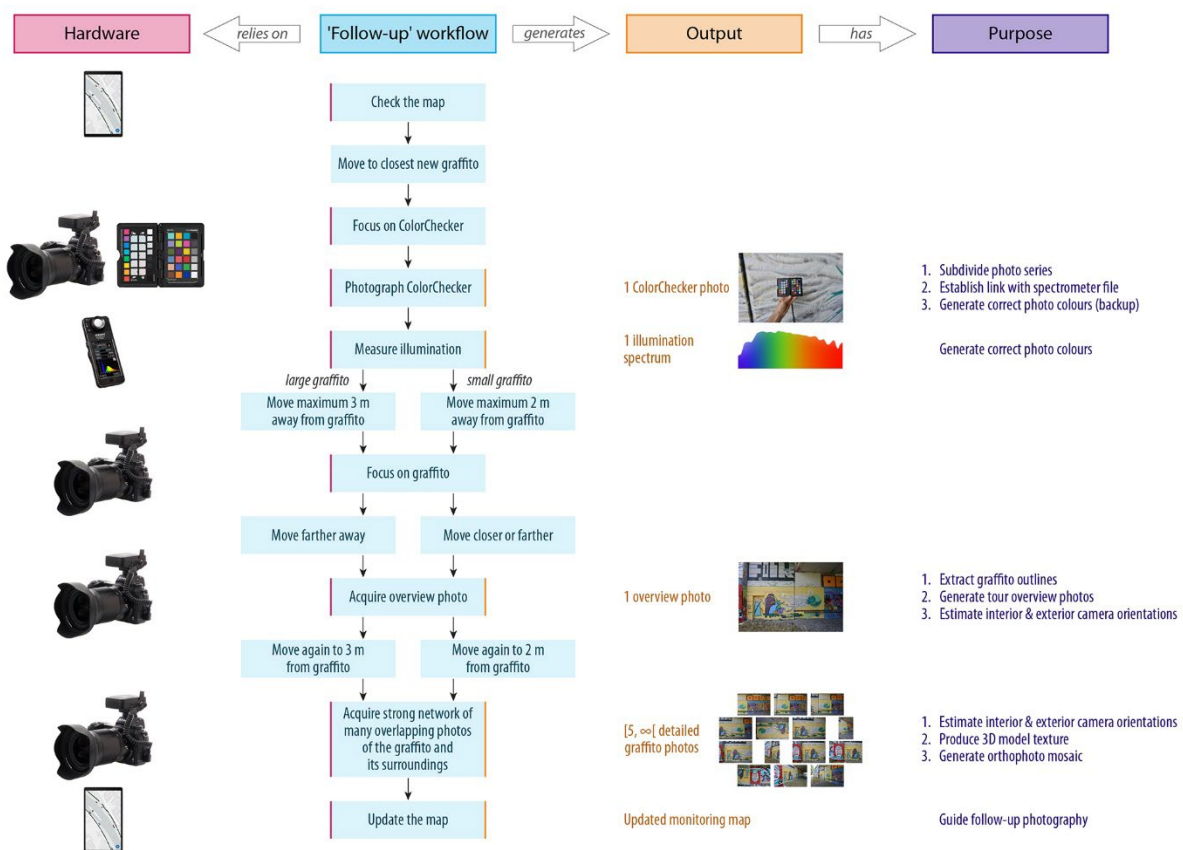

Figure 8 – Follow-up photography workflow for a new graffito. The illustration indicates the hardware needed and the purpose(s) of the generated outputs.

During the first year, the entire data acquisition and graffiti monitoring workflows (explained in Figure 8) witnessed several significant and minor changes. For example, no spectrometer was available initially, and the order of acquiring specific photos (like the overview photo or the photo of the ColorChecker target) was different. Even though a well-defined data acquisition workflow was fully established after six months,

minor mistakes still occurred now and then. Photographing two or more hours in a strict regime while juggling various hardware made it easy to lose focus. Working on days with extreme temperatures or in a rush did not help either. Besides thin gloves on frigid days, there was little potential improvement for these matters. Nevertheless, INDIGO still saw room for serious advancement in acquiring accurate coordinates for the camera stations. That was the focus of WP 6.

In addition to this follow-up photography, four moments for a total photographic coverage had been scheduled (September/October 2021 and 2022, March/April 2022 and 2023). The first of those coverages took place in October 2021. Spread over six days, a zone slightly exceeding INDIGO's entire research area (containing 13 km of graffitied surfaces; see Figure 10) was photographed in detail. In the first two days, the channel's embankments were photographed at a time when the water level was shallow. Photos from the left bank's wall were captured from the channel's right bank and vice versa (everything related to this acquisition is depicted in orange in Figure 9). During the last four days, all other surfaces were photographed (indicated with pink in Figure 9), generating 26.7k photographs altogether.

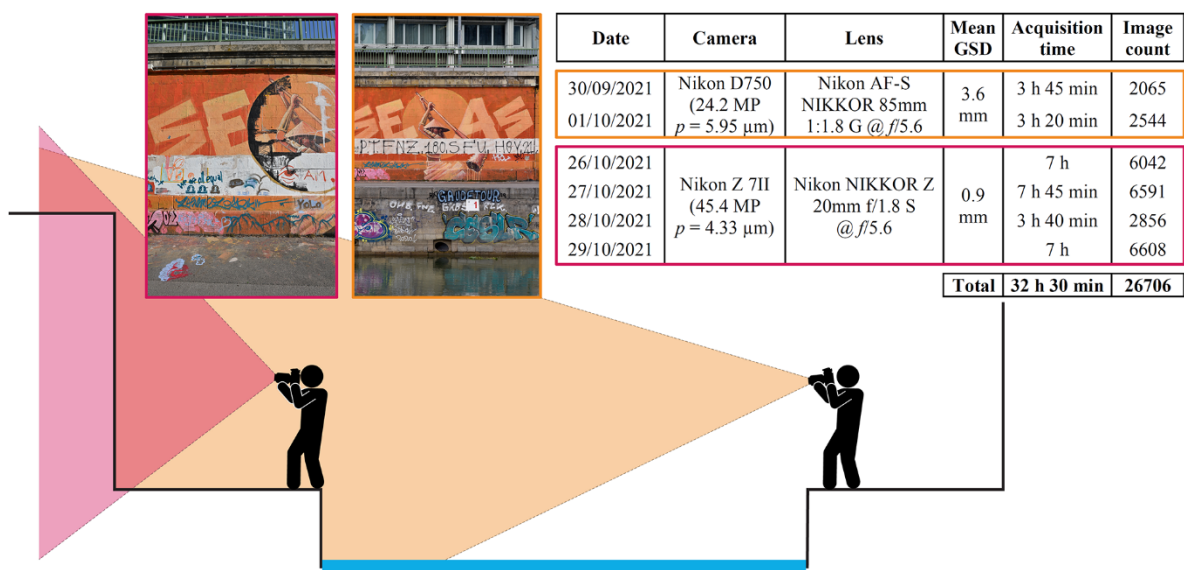| Date	Camera	Lens	Mean GSD	Acquisition time	Image count
30/09/2021	Nikon D750 (24.2 MP $p = 5.95$ μm)	Nikon AF-S NIKKOR 85mm 1:1.8 G @ f/5.6	3.6 mm	3 h 45 min	2065
01/10/2021				3 h 20 min	2544
26/10/2021	Nikon Z 7II (45.4 MP $p = 4.33$ μm)	Nikon NIKKOR Z 20mm f/1.8 S @ f/5.6	0.9 mm	7 h	6042
27/10/2021				7 h 45 min	6591
28/10/2021				3 h 40 min	2856
29/10/2021				7 h	6608
			Total	32 h 30 min	26706

Figure 9 – The total coverage photographic survey took place during two and four consecutive days at the start and end of October 2021, respectively. Both survey moments also utilised a different camera setup and acquisition strategy. This illustration uses orange (for the first two days) and pink (for the last four days) to indicate all the relevant data, the photographer's position and a sample photo of both photographic campaigns.

These photographs served three essential purposes:

- First, a digital 3D model that encodes the geometry of all solid surfaces along the Donaukanal could be computed from them (see Section A1-WP 7).
- Second, these photos created a graffiti status quo. They constituted a complete record of the graffiti-scape at a particular moment, thus effectively establishing INDIGO's starting point for tracking change in the graffiti-scape via follow-up photography.
- Third, those data enabled the efficient processing of new graffiti photographs. Within INDIGO, all graffiti photos acquired during the follow-up photography were processed into two end-products: geometrically corrected orthophotos and textures for a 3D surface model. The production of both products could be considerably sped up with knowledge about the camera's exact location and angular rotation when acquiring each of these total coverage photos. This process – and the necessary technical lingo – will be detailed in Section A1-WP 7.
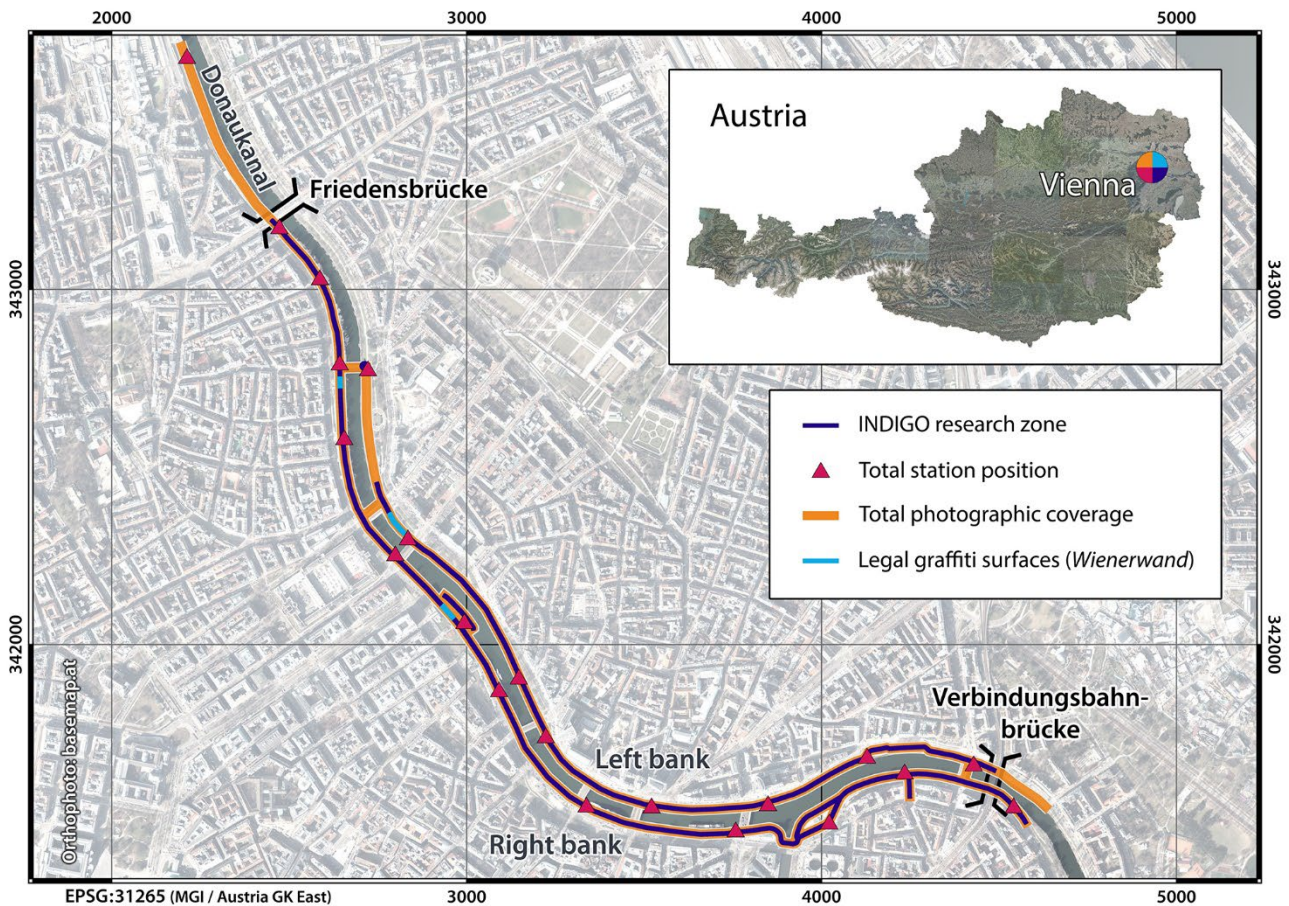
Figure 10 – All urban surfaces covered by project INDIGO (and the limited number of legal graffiti surfaces in this area). The illustration also depicts INDIGO's 2021 total coverage zone and the positions from where graffiti-scape points were measured (see Section A1-WP 7).

The initially planned four total coverage surveys aimed to record changes in the entire graffiti-scape that went unnoticed during the follow-up tours. However, the planned second and fourth total coverage surveys were omitted since implementing an image change detection approach proved more difficult than thought (see later, in Section A1-WP 11). Nevertheless, a new total coverage survey occurred in October/November 2022. This survey was the initially planned third survey, but it will now be called the second total coverage survey. The goal of this second total coverage survey was still to pick up graffiti change that had gone unnoticed before, but also to update the 3D digital surface geometry of the Donaukanal and achieve an even more complete 3D model (see Section A1-WP 7). That is why the main workflow remained unaltered, but two additions were implemented:

- Photographs were also acquired with the Nikon Z7 ii mounted on a hand-held photographic pole. The camera was fitted with a Samyang XP 10mm F/3.5 wide-angle lens, which made it possible to exhaustively photograph the walking surface and avoid holes in the entire 3D model (see the two photos on the left in Figure 11);
- A long series of photographs was also acquired from a boat showing tourists around the Donaukanal. The boat goes up- and downstream, which makes it possible to photograph both banks in a detailed manner and – as Figure 11 illustrates – the underside of all bridges.

Figure 11 – Two new types of photographs were acquired during INDIGO's total coverage survey. On the left are two photos shot with the camera and a 10 mm wide-angle lens fixed to a hand-held photographic pole. On the right is a photo acquired with the standard 20 mm lens during a touristic boat trip on the Donaukanal.

When	Who	Where	Purpose	Camera(s)	Lens(es)	GNSS device	Duration	Photo count
18/10/2022	Geert Verhoeven	Augartenbrücke -> Verbindungsbahnbrücke (right bank)	TC 2 (above-water surfaces left bank)	Nikon Z 7II-A	Nikon NIKKOR Z MC 105mm f/2.8 VR S	RTK GNSS-B	4 h	2693
19/10/2022	Geert Verhoeven	Verbindungsbahnbrücke -> Augartenbrücke (left bank)	TC 2 (above-water surfaces right bank)	Nikon Z 7II-A	Nikon NIKKOR Z MC 105mm f/2.8 VR S	RTK GNSS-B	4 h 10 min	4002
20/10/2022	Geert Verhoeven	Friedensbrücke -> Rossauerbrücke (right bank) and Siemens Nixdorf Steg -> Rossauerbrücke (left bank)	TC 2 (focus on horizontal surfaces)	Nikon Z 7II-A	Samyang XP 10mm F/3.5	RTK GNSS-B	3 h 10 min	3092
21/10/2022	Geert Verhoeven	Rossauerbrücke (left + right bank) -> Salztorbrücke (left + right bank)	TC 2 (focus on horizontal surfaces)	Nikon Z 7II-A	Samyang XP 10mm F/3.5	RTK GNSS-A & B	5 h 28 min	5929
24/10/2022	Geert Verhoeven	Both banks, but only partly (Salztorbrücke to	TC 2 (focus on horizontal surfaces)	Nikon Z 7II-A	Samyang XP 10mm F/3.5	Solmeta GMAX-A	1 h 45 min	1956
25/10/2022	Geert Verhoeven	Aspernbrücke to Verbindungsbahnbrucke, back to Marienbrücke (left bank) cross to right bank to Verbindugsbahnbrucke and return to Marienbrücke	TC 2 (focus on horizontal surfaces)	Nikon Z 7II-A	Samyang XP 10mm F/3.5	Solmeta GMAX-A	6 h 42 min	6931
26/10/2022	Geert Verhoeven	Both banks between Spitellau and Augartenbrücke.	TC 2 (above-water surfaces left & right bank)	Nikon Z 7II-B	Nikon NIKKOR Z 20mm f/1.8 S	Solmeta GMAX-A	1 h 12 min	2941
27/10/2022	Geert Verhoeven	Right bank between Friendensbrücke and 100 m before Rossauer Brücke	TC 2 (vertical surfaces above pathway)	Nikon Z 7II-A	Nikon NIKKOR Z 20mm f/1.8 S	RTK GNSS-A	2 h 3 min	2033
28/10/2022	Geert Verhoeven	Right bank between Rossauer Brücke and	TC 2 (vertical surfaces above pathway)	Nikon Z 7II-A	Nikon NIKKOR Z 20mm f/1.8 S	Solmeta GMAX-A	3 h 21 min	3766
29/10/2022	Geert Verhoeven	Right bank between Rossauer Brücke until end	TC 2 (vertical surfaces above pathway)	Nikon Z 7II-A	Nikon NIKKOR Z 20mm f/1.8 S	RTK GNSS-A	1 h 53 min	1939
31/10/2022	Geert Verhoeven	Left bank between the Siemens Nixdorf Steg -> Rossauer Brücke	TC 2 (vertical surfaces above pathway)	Nikon Z 7II-A	Nikon NIKKOR Z 20mm f/1.8 S	RTK GNSS-A	34 min	524
02/11/2021	Geert Verhoeven	Left bank form Rossauer Brücke until the end	TC 2 (vertical surfaces above pathway)	Nikon Z 7II-A	Nikon NIKKOR Z 20mm f/1.8 S	RTK GNSS-A	4 h 48 min	6284
							39 h 06 min	42090

Figure 12 – An overview of all individual total Coverage 2 acquisitions.

In the end, total coverage 2 produced 42k photographs (see Figure 12). All these photographs – and those of all other tours – are managed within the Digital Asset Management (DAM) system IMatch. DAMs ensure that renaming, moving, copying or deleting a specific file is also reflected in the other files. For instance, changing the metadata of a *.NEF photo (Nikon Electronic Format; Nikon's file format to store raw image data) should often lead to a change in the metadata of the corresponding *.JPG file. Or if the *.NEF file gets renamed, the related *.JPG file should adopt the same name. When managing files outside a DAM (like in Windows Explorer), such measures fail, leading unavoidably to file and metadata conflicts over time. IMatch and its tools use so-called buddy and sidecar files for which specific file relations can be defined.

IMatch also uses categories as one of the many ways to group data. Many of these categories are auto-generated, like lens type, camera model, and aperture. However, they can also be bespoke to, for instance, divide images into those of follow-up and total coverage tours. These categories are only held in IMatch and not written back to the file (like keywords would be). In other words, one can try virtually any kind of categorisation. IMatch also features many other ways to filter and sort resources – such as Events, Timeline (see Figure 13), and Collections (bookmarks, dots, flags, labels, ratings) – all without physically moving any files from where they are stored. Finally, IMatch also ensured all images featured correct copyright information and lacked metadata conflicts (which is hard to achieve in the jungle of photo metadata standards and inconsistencies in how software handle them).

2021	65.876	Q 3	6.760	September	6.760
		Q 4	59.116	October	51.372
				November	4.750
				December	2.994
2022	263.608	Q 1	30.049	January	3.739
				February	6.977
				March	19.333
		Q 2	27.524	April	8.472
				May	12.778
				June	6.274
		Q 3	48.242	July	12.768
				August	19.056
				September	16.418
		Q 4	157.793	October	116.611
				November	35.531
				December	5.651
2023	85.368	Q 1	25.300	January	7.934
				February	6.188
				March	11.178
		Q 2	31.312	April	7.748
				May	13.616
				June	9.948
		Q 3	26.932	July	6.670
				August	8.460
				September	11.802

Figure 13 – This photo timeline was automatically created by IMatch.

Finally, all *.NEF images and their *.XMP sidecar files (that contain most photo metadata) are stored as Adobe's *.DNG in ARCHE. All *.JPG files (from the GoPro cameras or generated along the *.NEF photos) are anonymised using the Celantur software (see the end of Section A1-WP12 for more information). This anonymisation operation is still ongoing due to the size of the photo collection.

WP 6 – GNSS/IMU

Initially, a Solmeta Geotagger GMAX was mounted on the camera. This unit uses the American GPS and Chinese Beidou satellite constellation to compute the camera's location with a precision of about 2.5 metres (at one standard deviation). This precision can be reached in ideal scenarios because the unit uses the correction signals broadcasted by the satellite-based augmentation system EGNOS (European Geostationary Navigation Overlay Service). The estimated geographical latitude, longitude, and altitude values are written into the Exif metadata of the *.NEF and *.JPG files. These values are leveraged in the orthorectification workflow (see Section A1-WP 9) for computational speed improvements. However, acquiring more accurate coordinates for every camera station was deemed helpful.

The INDIGO team has, therefore, developed a device to record the camera's exterior orientation (i.e., its position and angular rotation) when a photo is acquired. Built from commercially available but cost-effective components housed in a 3D printed case, this device connects to the hot shoe on top of the camera. It receives a Real-Time Kinematic (RTK) GNSS correction from the Austrian EPOSA service (Echtzeit-Positionierung-Austria), for which the settings get wirelessly controlled from a tablet or smartphone (Figure 14). INDIGO's internal tests indicated the potential to obtain centimetre-accurate coordinates and sufficiently correct rotation angles for each camera station.

The INDIGO team is very proud of this truly unique device. No other hardware solution offers this functionality out of the box. The most similar device on the market is the 3D ImageVector from REDcatch. However, handling the REDcatch device is more cumbersome due to its long cable and attached data logger. At the same time, the obtained camera rotation angles are much more inaccurate than those from INDIGO's device. Because of the Russian invasion of Ukraine and all the related supply chain issues, WP 6 had to deal with considerable delays. Specific electronic components arrived much later than expected; in one case, the needed piece became unavailable. Martin Wieser, who developed these devices, could only finish the first copy in August 2022 and a second one in September. After additional tests, both RTK GNSS devices were incorporated into the photography tours at the end of October 2022.

Figure 14 – The new RTK-enabled GNSS-IMU logging device (left and middle) with the interface controlling its settings (right).

However, bad luck struck in May 2023 when the lower part of one device (device B) broke (see Figure 15). Although such issues can quickly happen with proof-of-concept hardware, it also revealed some weaknesses concerning hardware development within academic projects. Martin Wieser was paid to develop these two devices, but repairs were not budgeted. Luckily, INDIGO's principal photographer, Stefan Wogrin, could continue the follow-up photography tours with device A.

Figure 15 – RTK GNSS device B with the broken connection part (photo by Stefan Wogrin).

Like Solmeta GMAX log files, these logs are available in ARCHE (see Section A1-WP15) as GeoJSON files with extra metadata. All log files from this device were processed with the RTKGNSS_Scene2MAP software from Martin Wieser. Although INDIGO cannot share this software, the project coordinator could freely use it. After processing, the camera's positional and rotational values are stored as metadata in an *.XMP sidecar file accompanying each *.NEF file. This approach to managing photo (meta)data is considered the only good practice within INDIGO.

WP 7 – 3D Geometric backbone

INDIGO aimed to document most new graffiti created along a large part of the Donaukanal via thousands of photographs that digitally encode the stratified graffiti-scape. The starting idea was that highly processed versions of these photographs would end up in a spatial database that feeds an online platform where users can freely and virtually visualise and query all graffiti records. Although that plan could not be finalised in INDIGO, all the foundations were created to materialise that plan in the future.

To provide clean and relevant data for the spatial database and online platform, i) three-dimensional (3D) surface geometry of the Donaukanal, ii) photographs of the graffiti, and iii) auxiliary data must be acquired. The 3D digital surface is vital to remove the geometrical photo deformations (see Section A1-WP 9). It is also the backbone onto which graffiti images will be mapped for display online.

As mentioned in Section A1-WP 5, a zone slightly exceeding INDIGO's research area (Figure 10) was photographed for six days in October 2021. Using techniques from the photogrammetric and computer vision fields (more specifically, Structure from Motion or SfM), it was possible to determine the camera's position and angular rotation for all 26.7k photos of this first total coverage tour (see Figure 16). In addition to these so-called exterior camera orientations, the SfM algorithm produced the camera's interior orientation parameters: a handful of variables that describe the camera's internal geometry (see Figure 16 for an example).
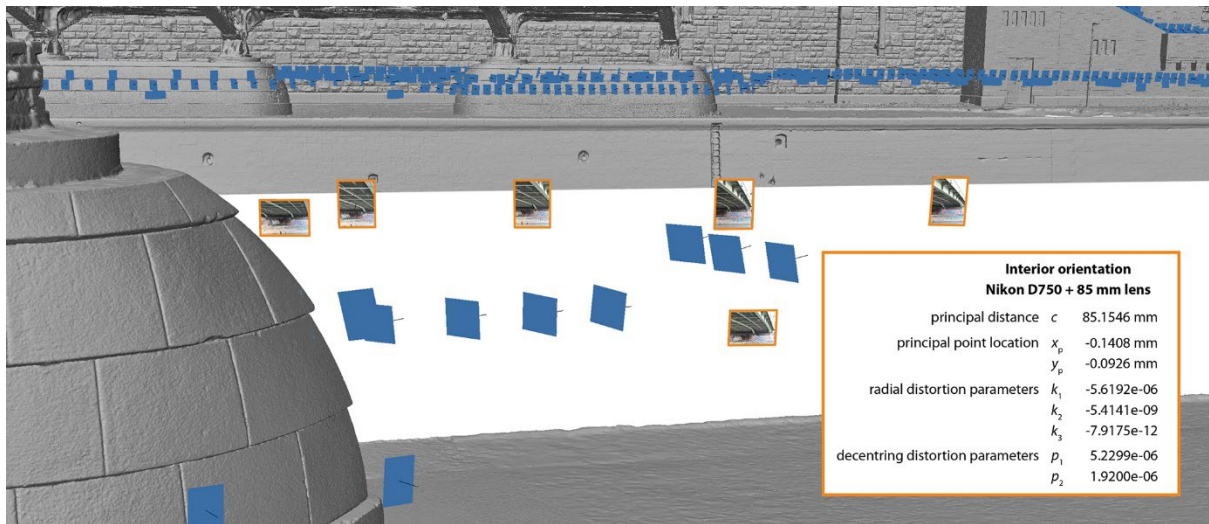
Interior orientation		
Nikon D750 + 85 mm lens		
principal distance	c	85.1546 mm
principal point location	x_p	-0.1408 mm
	y_p	-0.0926 mm
radial distortion parameters	k_1	-5.6192e-06
	k_2	-5.4141e-09
	k_3	-7.9175e-12
decentring distortion parameters	p_1	5.2299e-06
	p_2	1.9200e-06

Figure 16 – A portion of the polymesh that digitally represents the solid surfaces along the Danaukanal. The blue rectangles visually represent the exterior orientations of the camera stations. At the camera stations featuring an orange outline, a photo was captured from the opposite bank with a Nikon D750 camera plus an 85 mm lens. Those photos are shown inside the orange strokes, while the lower right inset provides the parameters describing the interior orientation of this camera-lens combination.

However, there was one problem with the approach mentioned above: the output of an SfM algorithm is expressed in an arbitrary coordinate reference system, meaning that the estimated positions and rotations of the circa 27k camera stations were only equivalent to their real-world values up to a global scaling, rotation and translation factor. The SfM output was embedded in a real-world coordinate reference system via a dense network of over 600 Graffiti-scape Points (GPs), measured during a multi-day total station surveying campaign (Figure 17). These GPs are object/scene points well-identifiable in many photos (even when potentially sprayed over) and whose long-term positional stability can be assumed (Figure 17, inset). Their coordinates were determined from one of the 21 total station locations that INDIGO established along the Donaukanal (see Figure 10). After indicating these 100s of GPs points in many thousands of photos, the SfM output could be accurately expressed in the MGI/Austria GK East coordinate reference system (EPSG:31256).
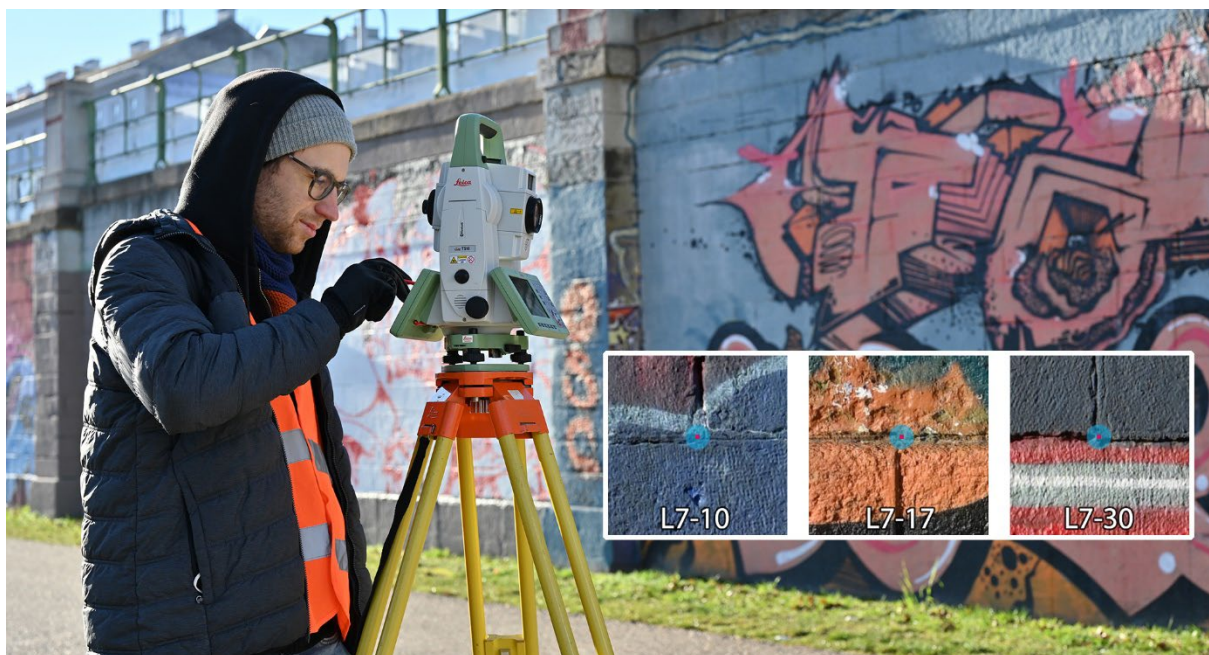

Figure 17 – Benjamin Wild operating the Leica Viva TS16 total station. The inset on the lower right displays three typical GPs.

As soon as all cameras were correctly oriented, it was possible to generate a continuous, digital 3D model that encodes the geometry of all solid surfaces along the Donaukanal. This is achievable via Multi-View Stereo (MVS), another photogrammetric computer vision technique. When given a set of detailed photos for which the image overlap is substantial, an MVS algorithm can produce a hole-free digital 3D surface representing fine geometrical features. Since this case meets both requirements, the well-known SfM-MVS software package Agisoft Metashape Professional could generate a preliminary, continuous 3D surface as a polymesh (Figure 16). Since INDIGO's envisioned online platform should offer virtual walks along the Donaukanal, this digital 3D surface model constitutes its geometric backbone.

The photo collection from the second total coverage tour (see also Figure 12) depicts the bridges and horizontal walking surfaces better than total coverage 1. However, the photos of total coverage 2 were only oriented, and no mesh was created. Creating this final 3D surface mesh is a very work-intensive task for which one can schedule circa three months. The problem lies in the number of photographs that must be processed (circa 42 k), making every operation very time-intensive. In addition, the final 3D mesh will be too large for usage online, so it needs to be simplified and segmented. Although the INDIGO team was familiar with these operations (since they were used to generate a mesh from the first total coverage photos), finding an extra pair of hands for this task proved impossible. As such, this work remains for a follow-up project.

WP 8 – Colourimetry

COOLPI

Colour is a powerful communication element in most forms of cultural heritage. This importance of colour notwithstanding, the documentation of cultural heritage typically focuses on the geometrical aspects and seldom the spectral dimensions of an artefact. This is partly because colour and the science of colour (called colourimetry) are non-trivial. In addition, capturing accurate colour data with standard digital cameras remains challenging due to the operating principle of standard imaging sensors and the need for a stable, non-variant illumination source. Despite these limitations, INDIGO made it one of its central aims to generate colour-accurate photos from graffiti captured with standard digital cameras in varying outdoor illumination conditions. To enable this, one of the primary intended deliverables was an open-source toolbox. Despite the contract problems (and resulting delays) with the Polytechnic University of Valencia, this software was finished by August 2022. INDIGO's COlour Operations Library for Processing Images (COOLPI) is available from its GitHub repository. At the same time, an extensive user manual is available at https://graffitiprojectindigo.github.io/COOLPI. Finally, a lengthy paper covers the basics of colourimetry and provides a detailed account of the colour-processing operations performed by cameras and COOLPI.

COOLPI was created by Adolfo Molada Tebar from the Polytechnic University of Valencia, Spain. Although Adolfo had initially planned to be in Vienna during the second project year to continue working on colourimetric problems – via a Margarita Salas grant that he won in the first months of project INDIGO – he was offered a job by the TIDOP research group at the University of Salamanca in mid-September 2022. This also meant that the planned research on colourimetry sadly stopped. For instance, in the first project year, a plan was born to create a graffiti-specific colour reference chart. Instead of photographing a ColorChecker target, the reasoning was that higher colour fidelity should be obtainable with a colour reference target featuring graffiti-specific colours. Throughout the first project year, colour swatch books of all major spraycan brands were bought to that end. Unfortunately, this initiative could not be pursued anymore. The idea would have been to collect the spectral reflectivity of all graffiti colour swatches with INDIGO's Konica Minolta CM-26d spectrophotometer, yielding a spectral database specific for graffiti spray paint that could open up new pathways for other researchers interested in the automated detection of graffiti (colours).

Spectrometer

Every series of graffito photos is complemented by a measurement of the solar spectral illumination using a Sekonic C-7000 SPECTROMASTER. These spectral data are essential to yield accurate image colours via COOLPI. However, this Sekonic instrument:

- Allows to download all the spectral data in a *.CSV file, but the language of that file depends on the Operating System's language. This led to files with German and English content, which had to be harmonised to English only.

- Writes files with a UTF-8 BOM marker, likely so they can be opened easily via Microsoft Excel. Excel never defaults to UTF-8 when opening *.CSV files, even when the file is encoded as UTF-8. Excel can, however, read the encoding properly if it finds a particular signature string at the beginning of a *.CSV file. This string is the UTF-8 BOM marker. However, the ARCHE repository (which stores all INDIGO data) advises against BOM. These *.CSV files thus needed to be resaved without BOM.

- Does not store the measurement's date and time, but only the date and time of downloading the data and creating the *.CSV file. This is problematic because each graffito photo series should have a spectral measurement. If the number of graffiti photo series does not match the spectrometer file count, it is not straightforward to determine which graffito lacks a spectral measurement.

There was thus a need to develop scripts to remedy these issues. These scripts – programmed in MATLAB – can all be found on [GitHub]. The left part of Figure 18 shows how a *.CSV file with German text gets resaved with English text. The numbers are stored to correspond with the original file. For example, spectral data always have twelve decimals in the original Sekonic files, also if the last eight decimals are 0. Other numbers have no fixed length. This function respects that, so it generates a *.CSV file as identical as possible to the initial *.CSV file by Sekonic. That entire conversion process also removed the BOM marker and altered the initial filename – which was partly determined by the spectrometer – to align with INDIGO's naming scheme (see Section A1-[WP 1]). Finally, the user can also generate a better-structured *.JSON file (Figure 18 on the right). The inset on the outer right of Figure 18 shows how the *.JSON file groups the initial Sekonic data into radiometric, photometric and colorimetric data, each again with appropriately named entries like chromaticityCoordinates and HelmoltzCoordinates.

Figure 18 – The initial *.CSV downloaded from the Sekonic C-7000 SPECTROMASTER features German text (left). INDIGO's script created an English version of this file with an INDIGO-conform filename (middle). On the right, the *.JSON variant is depicted, with the inset showing the collapsed lower portion of this file.

WP 9 – Orthorectification and texturing

Because INDIGO aimed to create an extensive digital 3D model with colour-accurate textures of the Donaukanal's graffiti-scape, spatially- and temporally varying textures had to be generated from the thousands of photographs acquired during the follow-up tours. This textured 3D model of INDIGO's envisioned online platform (see section A1-WP16) should allow users to view every graffito in its correct urban setting, both spatially and temporally. Suppose one also wants to study a graffito's dimensional, stylistic or semantic aspects. In that case, a highly detailed 2D orthophotograph could be viewed alongside the 3D model.

To deal with the massive amounts of photos and create textures for the 3D mesh along with orthophotos, the team developed the Python-based software AUTOGRAF (AUTomated Orthorectification of GRAFfiti photos). AUTOGRAF is distributed via INDIGO's GitHub. This free tool is an add-on for the popular software Agisoft Metashape Professional. It leverages the SfM and MVS functionality of Metashape. Still, it adds much automation and a few new functions so that graffiti photos can automatically be transformed into distortion-free graffiti orthophotos and mesh textures. After the initial release of AUTOGRAF, only a few optimisation tweaks and one new function were added: the possibility to project the image polygons created by GRAPHIS (see next WP) onto a 3D surface mesh. In December 2022, the paper describing AUTOGRAF was the cover story of the MDPI journal Heritage (see Figure 19).

Figure 19 – INDIGO's paper on AUTOGRAF is the Heritage cover story in December 2022.

WP 10 – Segmentation and annotation

GRAPHIS

WPs 10, 12, 13, 14, 15 and 16 are highly interrelated, and this relationship has proven technically and logistically challenging. Although progress was made in all of them, most WPs did not reach the anticipated end goal. Let us start with WP 10 and sketch the challenge.

The result of every photographed graffito should be:
- a 2D orthophotograph
- a texture patch for the 3D mesh
- a 2D polygon and 3D polyline to mark the border of the graffito
- subdivisions of that initial polygon/polyline to indicate which graffito segments are visible/invisible at a specific time. This output demands a tool that can compute and embed all the related fuzzy temporal information as metadata for these polygons/polylines
- a spatial database record storing all metadata about the processing stages and the temporal, contextual and contentual graffito metadata.

Since the graffito outline can speed up the orthophoto and texture patch generation, it is necessary to define the outer boundary of each graffito early in the processing pipeline. Ideally, this polygon is indicated on (and stored within) the overview photograph INDIGO acquired for each graffito. AUTOGRAF can read the boundary coordinates of this image polygon and project them onto the 3D mesh of that graffito (see the previous [WP 9](#)) to yield a 3D polyline defined in the Austrian coordinate reference system.

To enable the first part of this envisioned workflow, INDIGO has developed GRAPHIS. GRAPHIS (<u>G</u>enerate <u>R</u>egions and <u>A</u>nnotations for <u>PH</u>otos using the <u>I</u>PTC <u>S</u>tandard) is an open-source and [freely available](#) Python-based software to create, annotate, visualise and store image regions. Users can load one or more photographs into GRAPHIS and draw circles or polygons – either a rectangle or any arbitrary polygon – on them. Specific attribute data (like the creator of the region, the transcript of a text-based graffito or the unique identifier of that graffito) can be linked to each of such regions.

The backbones of GRAPHIS are two free and open-source software technologies: SQLite (https://sqlite.org/index.html) and ExifTool (https://exiftool.org). SQLite provides a self-contained, small and fast relational database engine. GRAPHIS' SQLite database stores links to the photos of interest and tracks every image region operation. This principle enables users to start/exit the software at will without the risk of losing work. It also enables collaboration on various photo collections, as each can have its own database. At any moment, the user can write the image regions back into the photo's metadata segment, an operation for which GRAPHIS utilises ExifTool, the Swiss army knife of file metadata manipulations.

Delineating the entire region occupied by a graffito usually relies on an arbitrary polygon with more than four edges. The polygon's boundary equals the border of the graffito. The polygonal region (i.e., the area enclosed by the closed polyline) corresponds to all image pixels that digitally depict that graffito. If a graffito consists of multiple parts (such as separated letters in verbal graffiti), a grouping of polygons or a so-called multi-polygon is needed to indicate all image regions that graffito occupies.

Indicating the polygon(s) is based on the overview photos INDIGO acquires during its follow-up photo tours. As soon as the border of a graffito is indicated on an overview photograph (see Figure 20), the coordinates of its vertices get stored in the GRAPHIS database. At the end of a GRAPHIS session, all newly indicated image regions and related metadata, like the region's creator and identifier, are saved according to the IPTC [Photo Metadata Standard](#) within the image file.
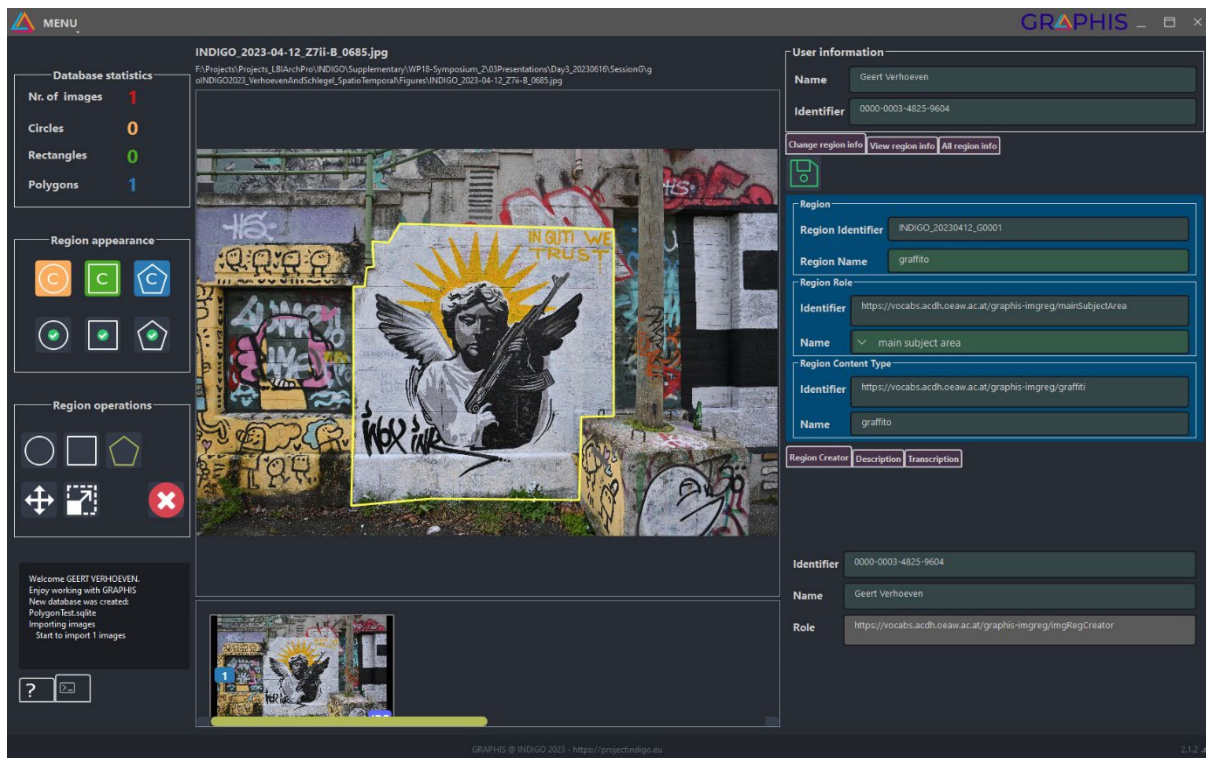
Figure 20 – A database with one overview photo is opened in GRAPHIS' graphical user interface. A 13-gon polygon indicates the graffito of interest. On the right, specific IPTC image region metadata get attached to this polygon: region identifier, region role, region content type, and region creator.

So far, GRAPHIS has been tested on various photo sets to ensure it can be used in a setting where one person polygonises tens to about a hundred graffiti overview photos per day. However, polygons were not created for all graffito photo sets. First, INDIGO lacked the human resources to do so. Second, GRAPHIS' output (and recorded metadata) must fit within an entire processing pipeline, and several of those components were in the making until the project's end.

Metadata annotation

GRAPHIS is an excellent example of how INDIGO tried to adhere to all possible standards, from photo metadata standards to semantic web rules. The development of a SKOS-based thesaurus illustrates the latter. The GRAPHIS Image Region Thesaurus (consultable here and explained in Section A1-WP13) is a small controlled vocabulary of eight terms in three groups containing all concepts to annotate image regions.

However, these annotations do not include what the graffito depicts; that is something entirely different and must be added separately. GRAPHIS is used to make the initial graffito polygon. However, this polygon (and its corresponding entry in the spatial database) must also store information on content, stylistic characteristics and temporality. Much of this information could be added to the images using photo cataloguing software such as Camera Bits' Photo Mechanic Plus or Photools' IMatch (both available in project INDIGO). These solutions would embed the necessary metadata in the image or an *.XMP sidecar file. OpenAtlas (INDIGO's database solution; see Section A1-WP 14) could then read this *.XMP metadata. However, this workflow was never thoroughly tested as much development time (a magnitude more than expected) went into the basics of INDIGO's metadata annotation system: the graffiti thesaurus (see also Section A1-WP13).

Graffiti research is notorious for using a wide variety of unstandardised terms, which prevents analysis on a larger-than-local scale. For example, suppose database A labels a creation 'graffito', while database B

considers the same work as 'street art'. In that case, cross-database queries would lead to partial results and conflicts. Even if multiple people enter data into only one database, the fact that they might be using different personal definitions for the same terms could render that database unusable. To avoid the inaccurate, biased or even impossible analysis that stems from too much terminological elasticity, project INDIGO created a broad, graffiti-centric thesaurus. Although the project proposal has highlighted the challenges related to this complex interaction, it is mainly due to delays of (and the necessary work put into) the thesaurus that other WPs got behind schedule. Nevertheless, that terminological basis is now ready to be used by everybody in graffiti research and a potential INDIGO 2.0 follow-up project.

To end this section on a positive note: project INDIGO established connections to some of the most authoritative people in the fields covered by these interrelated WPs. For instance, to ensure that storing and reading image metadata would follow all established standards (which almost no software is currently capable of), connections were made with various developers of photo management tools and David Riecks. Mister Riecks is a metadata evangelist, founder of ControlledVocabulary.com and co-lead of the IPTC Photo Metadata Working Group. Although collaborating with these experts lengthened the metadata annotation development – because it revealed new issues which are barely covered in the scientific literature – these delays were considered a necessary evil. INDIGO wanted to raise the bar in cultural heritage documentation, dissemination and digital preservation by improving some of the current approaches in digital humanities. As such, at least INDIGO's primary data (i.e., several 100,000 photographs) should feature maximum metadata compatibility, have proper metadata annotation, and adhere to complex standards.

WP 11 – Change detection

Main idea

The initial idea of image change detection was related to the total coverage tours, of which the last three should help detect previously undocumented graffiti via automated change detection. First, only two total coverage tours took place (see Section A1-WP5). Second, developing a robust change detection algorithm has proven to be complicated. Third, the INDIGO photographers realised that the monitoring strategy (finding new creations via Instagram or relying on visual memory when walking/biking along the channel) was insufficient to spot minor graffiti. That is why a new monitoring approach was born, still centred around image change detection.

The envisioned workflow goes like this. Two GoPro HERO10 action cameras are mounted on a camera bar. The bar connects to a handgrip, allowing the dual-camera construction to be handheld. Because the camera lenses point in approximately opposite directions, one can photograph nearly every surface above and below the walking/biking path by biking once on each side of the channel (see Figure 21).
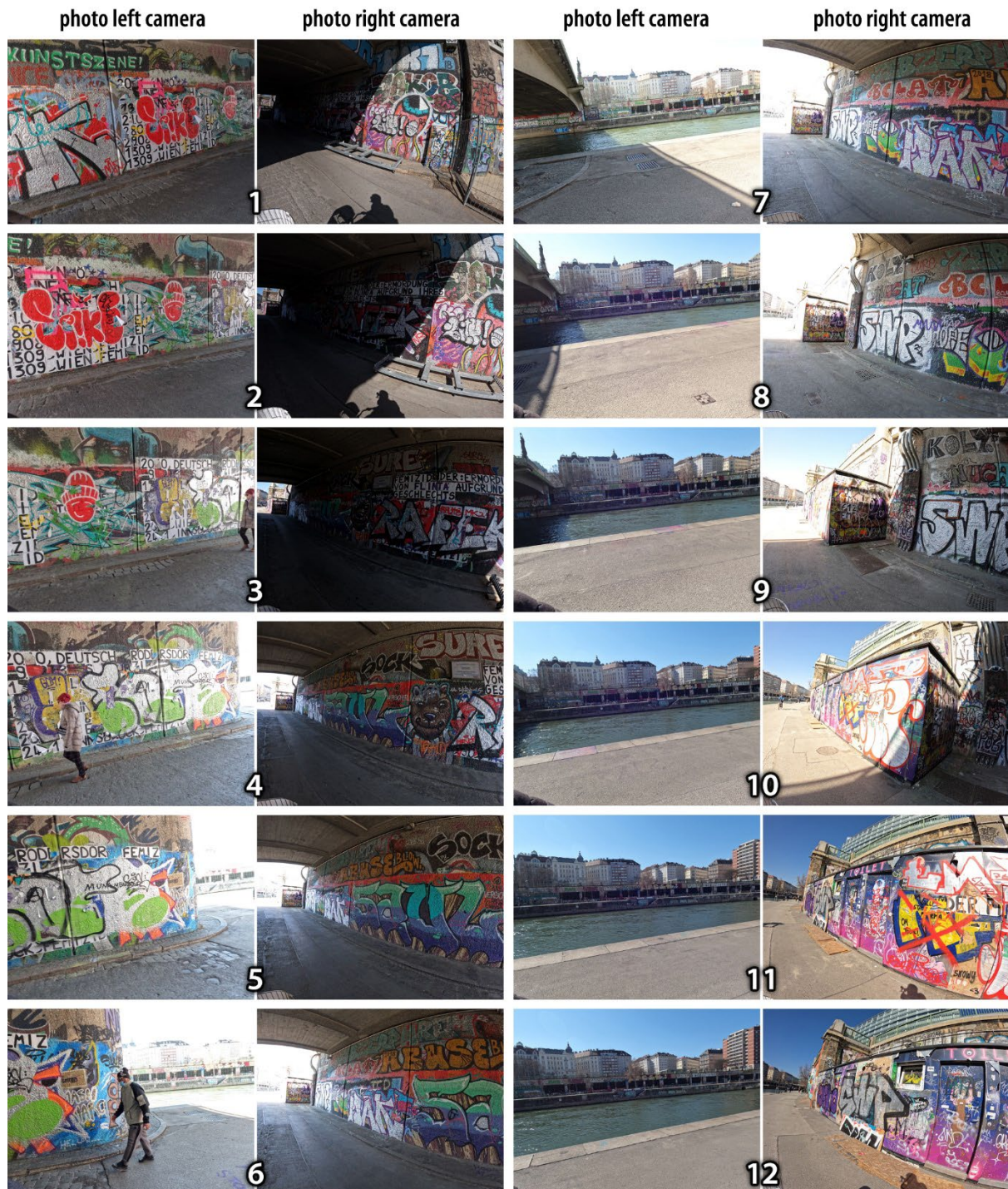
Figure 21 – A sequence of twelve left-right photographs acquired from the Donaukanal's left bank.

Using the previously mentioned SfM approach (see section A1-WP7), the exact exterior orientation of each camera station is retrievable. Imagine a GoPro photo series acquired during a one-hour biking tour on Monday morning and correctly processed with SfM by Tuesday afternoon. At that point, one can compute a meshed 3D surface of these images using an MVS algorithm (Figure 22A). Once the mesh is ready, it can be textured with the photographs (Figure 22B). After a rainy night, a new GoPro photo series is collected on Wednesday morning. Because an incremental SfM approach can leverage the network of oriented Monday photos (i.e., the dark blue rectangles in Figure 22C), the position and rotation of the newest camera stations (symbolised by the light blue rectangles in Figure 22C) are estimated by Wednesday evening.
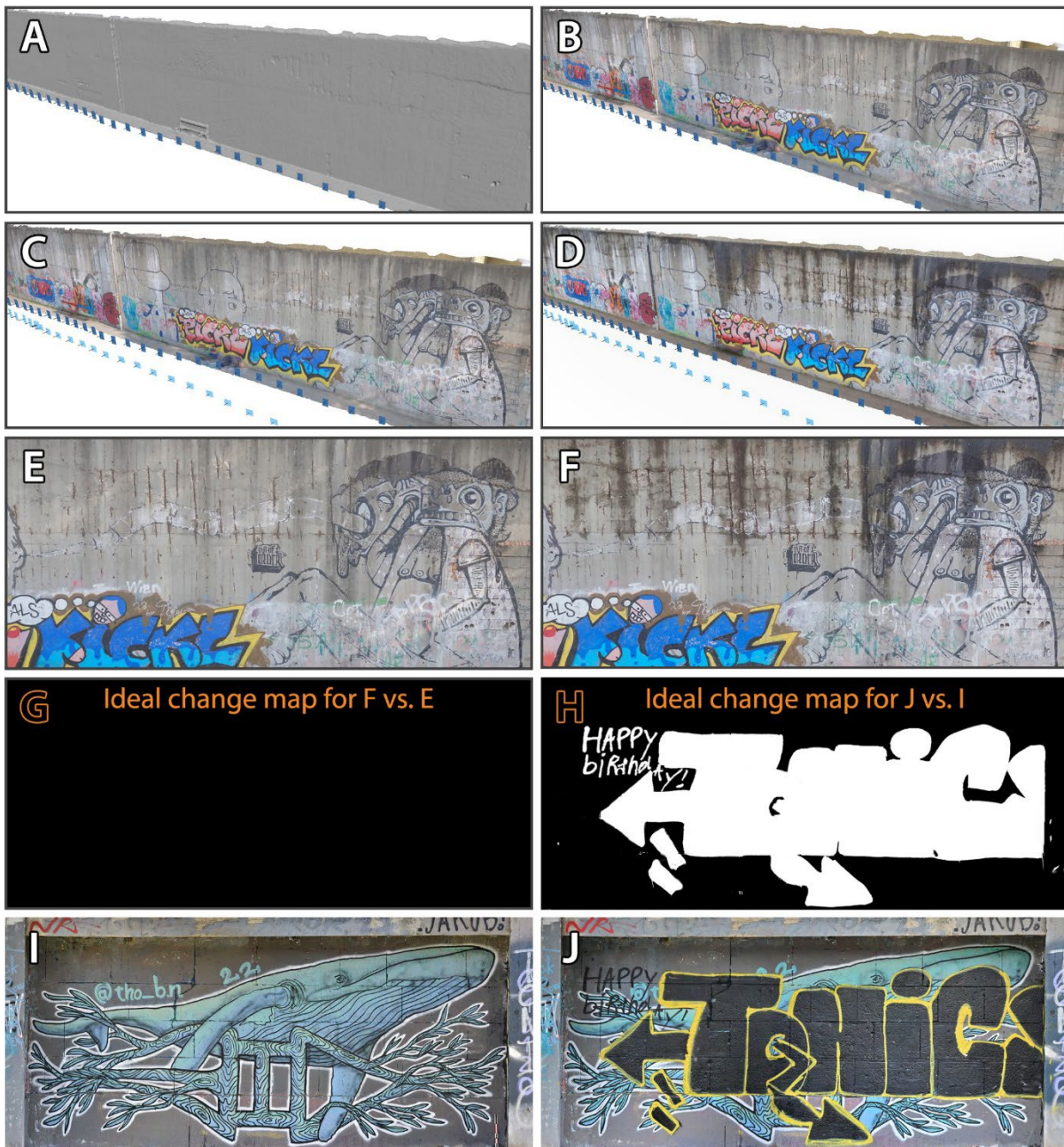
Figure 22 – The insets A to D explain how two photo events could result in two pixel-perfect aligned textures (E and F), from which one could extract a change map. In this case, the change map (G) should be blank because all changes that occurred are unrelated to the graffiti. This is not the case for the scene changes between insets J and I. Here, inset H depicts the ideal change map. Both change maps were manually generated with Adobe Photoshop 2022.

At that stage, the mesh computed on Monday gets textured with the Wednesday photographs Figure 22D) so that two textures exist, partly displayed in Figure 22E and Figure 22F. Ideally, these texture images are pixel-perfect aligned so one can look for differences between any two pixels at any location. In its most simple way, this last step could subtract the Monday texture from the Wednesday texture to yield a so-called change map or change image. Since this change map depicts any relevant difference that occurred in the graffiti-scape between Monday and Wednesday, it is a perfect guide for the follow-up photography tour on Thursday.

However, the hard part of this workflow proved to be the change detection step. INDIGO tested many algorithms, but most were incapable of robustly computing graffiti-relevant change maps in a reasonable amount of time. The challenges to this problem predominantly lie in the large pixel counts of the images and

the different photo renderings of an unchanged scene. Let us consider the last issue. Photographing an invariant graffiti scene once in cloudy conditions and once in harsh sunlight will result in two photos that look different. Not only might the colours look distinct, but the sunlight will generate strong shadows that are absent in the other photograph. Although a human quickly understands that the graffiti-scape did not change, designing an algorithm robust to these graffiti-irrelevant photo differences proved hard. The same problem occurs after a rain shower. The ideal change map (Figure 22G) between Figure 22E and F is blank because the only scene variation between both photo events relates to rainwater running down the concrete (see Figure 22D and F).

These challenges notwithstanding, INDIGO has made significant advances in this area and produced a reference dataset useful for benchmarking other research groups' change detection algorithms.

Reference dataset

To test the effectiveness of the change detection algorithms during their development, the INDIGO team decided to build a test dataset with manually created change maps. The generation of this dataset started with the acquisition of photographs. Between the 21st of October 2022 and the first of December 2022, eleven photographic acquisitions of the INDIGO test wall took place. This circa 250 m long test wall includes the legal graffiti surface on the left Donaukanal bank, indicated in light blue in Figure 10. Photographs were acquired with three GoPro cameras (2x HERO10 black and 1x HERO11 black) mounted inside a frame composed of standard camera rig components (see Figure 23). The cameras were mounted as closely as possible, with the optical axes mutually parallel.

Figure 23 – Three GoPro cameras mounted inside a frame composed of standard camera rig components.

The GoPro camera settings were changed for every photo acquisition to cover all possible camera settings-weather combinations. Each of these so-called epochs thus counts three GoPro subsets. Every subset consists of two photos per second, acquired with the three-camera frame while walking at a usual 5 km/h pace.

All the photographs were oriented using the SfM approach explained above. Then, one mesh was computed from these photos. That mesh was textured with each photo series acquired on a specific day with one of the

three GoPros, yielding three variably textured meshes per acquisition day, one for each GoPro camera with its specific settings. Figure 24 shows three different textures, generated from the photos by the GoPro HERO11 black on three different days. The textures displayed in Figure 24 are epoch-specific textures from which the actual changes in the graffiti-scape must be extracted. However, having three diverse textures per day (each depicting the same graffiti situation) is also essential to study the robustness of the change detection algorithm to differing sharpness and contrast levels.

Illustration by Benjamin Wild

Figure 24 – The upper left image shows the position of INDIGO's GoPro HERO11 black photos acquired on three days. The same 3D meshed surface model of the test zone can be textured with these photographs to yield epoch-specific textures. Illustration by Benjamin Wild.

Then, a small part of this test wall mesh was extracted, and 17 synthetic cameras were defined inside Agisoft Metashape Professional 1.8.4. From these synthetic cameras, a view was generated for each possible texture. In that way, one avoids dealing with massive textures but resorts to smaller artificial/synthetic photos (which still look real because they are generated by observing a mesh texture from real photos). Since the synthetic cameras stay invariant, all images computed from such a camera are perfectly co-registered.

All these synthetic images led to 6,902 unique image pairs; the photos of every pair can either show an invariant graffiti-scape or document some change. To use this test set for benchmarking, a reference change map and an exclusion mask (to ignore parts of the scene that might be irrelevant, such as the background) were manually or semi-automatically defined for all these pairs. This unique dataset, which aims to support developing and assessing image-based change detection algorithms, has been made publicly available here.

Algorithm

After many months of testing, INDIGO produced a novel hybrid image-based change detection framework tailored for graffiti change analysis. The proposed approach synergises a pixel-based and a descriptor-based technique to detect changes within the graffiti-scape while ignoring image disparities unrelated to graffiti alterations. All details of this approach can be read in a forthcoming paper (see section A3).

WP 12 – Image processing

This WP wanted to integrate and apply all the colour correction, orthorectification, segmentation and annotation tools on the photos collected during years one and two. Although the COOLPI and AUTOGRAF workflows were integrated at the start of year two, the exact order of all processing steps changed a few times throughout the project. First, there was a need to develop new software. Second, the operating principles of this software made us rethink the entire processing pipeline. Two examples can illustrate this:

- It was clear from the beginning that segmentation software was needed. However, once GRAPHIS (see Section 1A-WP10) was being developed, it became clear that AUTOGRAF could use the GRAPHIS polygon to speed up specific steps. Moreover, one could also do the first graffito classification in GRAPHIS, but then it should have the graffiti thesaurus integrated. At that time, however, the thesaurus was not ready yet. And even if it would, does it make sense to classify the graffito already at that stage? Whereas everybody can do graffiti segmentation, it is preferable to have each graffito classified by somebody knowledgeable about graffiti. Considerations like this often changed the basic order of processing steps, but it also revealed a need to 'objectify' the classification rules for graffiti. More info on this will be given in Section A1-WP14.

- Only when the team crystalised the needs and the goals for the online graffiti dissemination platform did it become apparent how important it was to track, query and visualise the temporal aspect of graffiti. This explains why INDIGO's research on spatio-temporality did not have its own WP, despite the substantial brainstorming and coding effort that was allocated to it. First, there was a need to define which temporal information would be relevant and how this could be modelled within CIDOC's CRM and then the spatial database OpenAtlas (see Section A1-WP14). Many brainstorming sessions and coding attempts led to the temporal blocks illustrated in Figure 25. The lower part of that figure depicts the GeoJSON structure that was defined to hold the polygon's vertices along with all temporal metadata. These graffito-specific GeoJSON files are then subjected to various spatial and temporal operations inside INDIGO's prototype software POLYGRAF. With POLYGRAF, the INDIGO team hoped to automatically record which graffito part is (in)visible at a given time. The POLYGRAF code has not been shared yet, as the software is still unfinished. Despite the essentiality of recording and analysing time in archaeology, there are barely tools to do so. That is why POLYGRAF will be developed further by the project coordinator in 2024. However, the inputs and outputs of POLYGRAF will determine where it can fit in the entire processing pipeline.

Figure 25 – The temporal events and states which project INDIGO records per graffito in a GeoJSON file.

INDIGO could have left the temporary aspect of graffiti aside. That would, however, have led to a database and online platform that would not improve upon existing platforms, nor would it yield a good research dataset, as many exciting questions rely on the temporal aspect (which is missing from all graffiti databases). That is why the project coordinator approached all INDIGO's research topics qualitatively rather than quantitatively, thus building a solid basis for hopefully a follow-up INDIGO 2.0 project. It is also important to mention that all these considerations, thought processes and final solutions were published (see Section A3) so they can benefit other scholars.

The same rigour was applied to the photographs and their metadata. INDIGO tried to adhere to all essential metadata standards. That is a complex task for photos, as their metadata landscape is utterly complex, and almost no camera manufacturer or software developer strictly follows all standards. In short, INDIGO put much effort into compliance with the prevailing IPTC Photo Metadata Standard. This meant many bespoke programming efforts, not only in the form of image pre-processing scripts but also for the GRAPHIS software. For example, the Nikon cameras used by INDIGO embed a rudimentary XMP record (XMP is one of the many photo standards). However, none of the Exif tags (which are metadata written in the image by the camera) are mapped to the corresponding XMP tags, which might lead to metadata inconsistency.

Much software also does not manage image metadata properly. For example, Photo Mechanic – a viewer and metadata tagger many pro-photographers use – writes legacy IPTC-IIM tags. This is a bad practice, but it is understandable as photo software typically only supports the depreciated tags. Since INDIGO's image processing tools were programmed by the team (besides the professional DAM IMatch, which follows all metadata standards as closely as possible), there is no need to rely on these legacy tags. Therefore, MATLAB- and Exiftool-based scripts were made to check photos for these legacy metadata fields and delete them. This is only one of the many checks INDIGO implemented to enforce proper image metadata.

Finally, photo anonymisation became an initially unanticipated part of the processing pipeline. Often, it is unavoidable to have by-passers in the photo. Since INDIGO data are publicly available via ARCHE, anonymising each person or relevant personal data like number plates was paramount. Again, detection robustness and speed of execution were critical. Luckily, INDIGO could collaborate with Celantur. Celantur specialises in the anonymisation of still images and videos. The software blurs faces and can anonymise entire bodies, also when people are partly obscured (Figure 26A-B) or depicted as tiny figures in highly overexposed parts of the photo (see Figure 26C). In addition, Celantur's software can deliver binary photo masks, which can be applied at several stages of INDIGO's image-processing workflow.
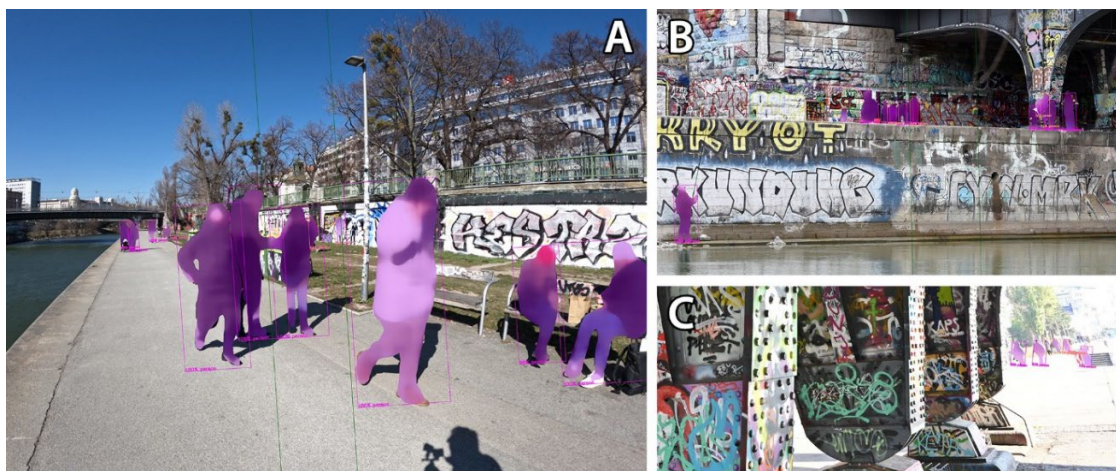

Figure 26 – The binary masks (applied in purple) generated by Celantur's anonymisation software. Entire bodies can be masked, irrespective of people's distance to the camera (close in A or very far in C). Partial occlusions (A and B), busy graffiti backgrounds (B) and overexposure (C) did not seem to impact the software's performance.

WP 13 – Thesaurus

Graffiti Thesaurus

Any graffiti analysis depends on how graffiti are defined and classified. For example: some scholars and graffitists voice that legally permitted graffiti do not deserve the label 'graffiti'. Even though such terminological distinctions do not guide INDIGO's recording, the project had to strive for terminological clarity to populate the database with unambiguous metadata. The creation of a graffiti thesaurus accomplished this. Being a finite set of terms (i.e., a controlled vocabulary) with hierarchical relations, this thesaurus made INDIGO's classification explicit, hoping to serve as a reference for the broader academic graffiti community. Since the thesaurus is considered one of the essential project deliverables, it has received substantial attention. However, its construction has proved challenging, not in the least because of the difficulty of defining graffiti itself. As a concept, graffiti is used in archaeological circles to describe ancient Roman inscriptions. However, it is equally well-used by sociologists and art historians to talk about colourful contemporary sprayings. Being an archaeological and heritage science project, INDIGO considered all major and minor aspects of the term in its thesaurus. Based on this general definition, related concepts like street art and mark-making were defined, as are the countless graffiti subcategories.
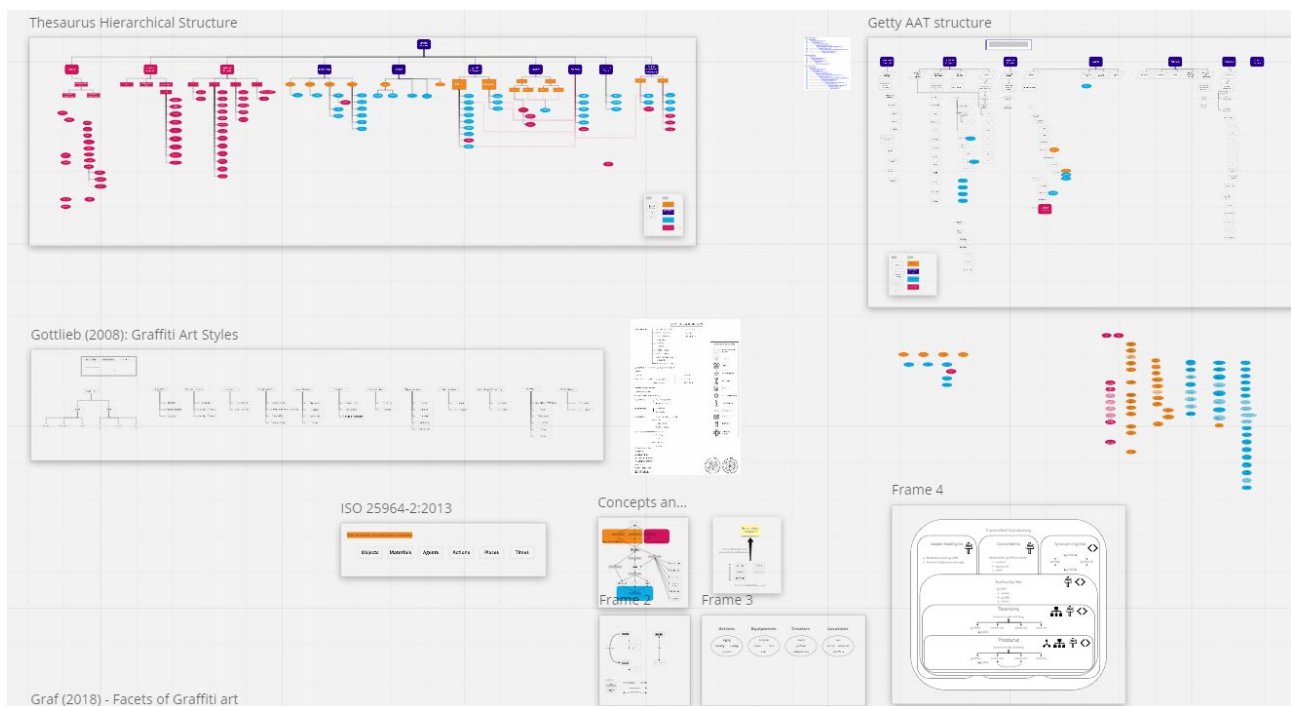

Figure 27 – Some different structures developed in MIRO to structure the graffiti thesaurus.

Besides some fundamental problems in defining overarching terms, hierarchically structuring them has also proven challenging. Many designs were proposed in the first project year (see Figure 27 for some examples). Discussing those designs was not always straightforward since experts on thesauri are not, per se, experts on graffiti and vice versa. INDIGO contacted the Getty Research Institute (the author of the authoritative Getty Art and Architecture Thesaurus, or Getty AAT) and influential scholars like Ann Graf to aid us in this process. Ultimately, the team reached a consensus to model the thesaurus after the Getty AAT, the world's most-known heritage thesaurus.

During the entire project, INDIGO has devoted significant research to creating this thesaurus of 179 graffiti concepts and ensuring it is embeddable into the Getty AAT. Despite that effort, the concept definitions were not made public yet, since time failed to define all terms consistently and exhaustively. The project

coordinator intends to continue working on these definitions, aided by the below-mentioned Graffiti Terminology Database.

The INDIGO thesaurus was initially developed in MIRO and via a few shared Google spreadsheets. Later, the entire process was ported to INDIGO's GitHub, which was ideal for joint working, versioning, tracking and documenting the entire development process. For example, GitHub now hosts a very extensive README that provides much background information about the thesaurus. In addition, the thesaurus is available as a *.TSV (Tab-Separated Values) and *.JSON (JavaScript Object Notation) file. However, neither GitHub nor these file formats are ideal for interacting with the thesaurus. That is why the final **INDIGO Graffiti Thesaurus (version 1.0.0)** is located at https://vocabs.acdh.oeaw.ac.at/indigo/Thesaurus, hosted via the Vocabs service of the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH).

Via Vocabs, a user can either manually browse through the concepts or programmatically access them via the API (Application Programming Interface). Vocabs runs on Skosmos and is ideal for disseminating the thesaurus in the SKOS format. The ACDH-CH ensures that the Uniform Resource Identifier (URI) for this graffiti thesaurus (i.e., https://vocabs.acdh.oeaw.ac.at/indigo/Thesaurus) and the URIs for all of its concepts (e.g., https://vocabs.acdh.oeaw.ac.at/indigo/graffiti) remain permanent. So, whereas GitHub enables working on the underlying structure of the thesaurus, Vocabs integrates it into the semantic Web, making the thesaurus and its single concepts (as well as the collections to which they belong) findable, accessible, and reusable.

The thesaurus' concepts and structure went through many iterations, a process supported by the 100s of different resources (books, articles, magazines and movies) the project team consulted. This, in turn, led to two related outputs:

- **INDIGO Graffiti Terminology Database**. In the existing body of popular and scholarly graffiti literature, one finds many glossaries, lexicons and other lists of terms to describe graffiti-related terminology. Although these solutions all come with one or more disadvantages (see this paper by the INDIGO team for more info), collecting all these resources helped shape INDIGO's graffiti thesaurus. In addition, this collection of terminology lists can be helpful for anyone who wants to compare how different authors define the same graffiti-related term. That is why this terminology dataset was published as the INDIGO Graffiti Terminology Database. This dataset currently holds 2134 definitions (1728 in English, 303 in German, 61 in French and 42 in Italian) from 48 sources. It is made freely available over Zenodo as a text-based *.TXT file (where all the values are tab-separated) and a Microsoft Office Excel *.XLSX spreadsheet file (which also provides extra information about the sources consulted).
- **INDIGO Graffiti Literature Database**. During the project's duration, graffiti-related literature (with their PDF, if available) was collected in a closed-source Citavi and an open-source Zotero database. At first, this database only collected the graffiti resources consulted by the INDIGO team to create the thesaurus. Later, all encountered references were incorporated (but not without properly checking all bibliographic information), leading to a continuously increasing reference database. This database of almost 1250 references is now directly accessible as a Zotero project, or one can download it as a Zotero *.RDF, a BibTex or Citavi variant (DOI: 10.5281/zenodo.8419328).

Image Region Thesaurus

INDIGO's bespoke image segmentation tool GRAPHIS can annotate image regions (see Section A1-WP10 or here). Image regions are shapes like rectangles, circles or any possible polygon that can be marked and saved within an image. The IPTC Photo Metadata Standard has enabled storing these image regions since its 2019.1 version. GRAPHIS (Generate Regions and Annotations for Photos using the IPTC Standard) provides a graphical user interface to generate, visualise and annotate these image regions while adhering to the IPTC

Photo Metadata Standard. All concepts used by GRAPHIS were defined in the **GRAPHIS Image Region Thesaurus**, a small controlled vocabulary of eight terms in three groups containing all concepts to annotate image regions:

- *content production contributor roles*
    - description writer
    - image region creator
    - transcript writer
- *image region roles*
    - area of interest
    - main subject area
    - subject area
- *image region types*
    - graffito
    - text (graffito).

The Vocabs service of the ACDH-CH also hosts this thesaurus, which can be found [here](.).

WP 14 – Spatial database

OpenAtlas

Collecting and processing data without a sound data management system is irresponsible. This WP aimed to create a spatial database to manage and query all (meta)data. The need for robust database integration with the online platform (see Section A1-[WP 16](.)), support for spatio-temporal queries, and adherence to the [CIDOC CRM ontology](.) standard made this task challenging. At the same time, data entry should be customisable and painless. INDIGO had chosen the CIDOC CRM-based [OpenAtlas](.) database framework as its solution.

Because INDIGO deals with spatially 3D data and many graffiti only live for a few days, two specific but profound OpenAtlas changes were needed: 1) the support for 3D geometries and 2) a temporal resolution smaller than one year. Because OpenAtlas mainly served historical projects before INDIGO, also other changes were needed:

- Additional classes and properties of the [CIDOC CRM](.)
- API extensions for [ARCHE](.)
- API extensions for [Vocabs](.)
- Improved documentation

Over the past two years, the OpenAtlas team has worked on these INDIGO requirements, which has led to a whole assortment of new technical implementations:

- **OpenAtlas version 6.6.0**
    - #1500 Production of artifacts – https://redmine.openatlas.eu/issues/1500
- **OpenAtlas version 7.0.0**
    - #1579 API: Include Swagger documentation – https://redmine.openatlas.eu/issues/1579
- **OpenAtlas version 7.3.0**
    - #1498 Remove types with subs and/or linked entities (preparation for Vocabs import) – https://redmine.openatlas.eu/issues/1498
    - #1501 Set multiple choice types to single type (preparation for Vocabs import) – https://redmine.openatlas.eu/issues/1501

- o #1631 Join database GIS tables – https://redmine.openatlas.eu/issues/1631
- **OpenAtlas version 7.4.0**
  - o #1500 Production of artifacts – https://redmine.openatlas.eu/issues/1500
  - o #1574 Dates with hours, minutes and seconds – https://redmine.openatlas.eu/issues/1574
- **OpenAtlas version 7.5.0**
  - o #1710 Manual: add CIDOC links for entity classes – https://redmine.openatlas.eu/issues/1710
- **OpenAtlas version 7.7.0**
  - o #1587 Link artefacts and human remains to places – https://redmine.openatlas.eu/issues/1587
  - o #1790 Map: make intersecting polygons selectable – https://redmine.openatlas.eu/issues/1790
- **OpenAtlas version 7.8.0**
  - o #1647 Composition of artefact and human remains – https://redmine.openatlas.eu/issues/1647
- **OpenAtlas version 7.10.0**
  - o #1848 API: fetch data from ARCHE – https://redmine.openatlas.eu/issues/1848
  - o #1934 New creation event class – https://redmine.openatlas.eu/issues/1934
- **OpenAtlas version 7.11.0**
  - o #1943 Auto rotate image – https://redmine.openatlas.eu/issues/1943
- **OpenAtlas version 7.13.0**
  - o #1952 E11 Modification – https://redmine.openatlas.eu/issues/1952
- **OpenAtlas version 7.15.0**
  - o #1991 Import controlled vocabularies via API – https://redmine.openatlas.eu/issues/1991
- **OpenAtlas version 7.16.0**
  - o #2040 ARCHE import script – https://redmine.openatlas.eu/issues/2040
  - o #2048 Import Vocabs collection – https://redmine.openatlas.eu/issues/2048

It is important to note that these INDIGO-related features also benefit other projects that rely on OpenAtlas, since all projects have the same database functionality at their disposal. Extending and improving OpenAtlas was thus beneficial for many. Sadly, INDIGO did not manage to put all of its data in OpenAtlas due to reasons mentioned at the start of Section A and in Section A1-WP12. This section will iterate only one of these reasons: the difficulty of modelling and querying temporal information.

Spatio-temporal queries were a big deal for INDIGO, but temporality is typically given very little attention in archaeology. This also explains the lack of tools to deal with the temporal aspect of cultural heritage, despite being one of its core characteristics. Given the detailed temporal data collected in the project, INDIGO hoped to improve upon the state-of-the-art in this aspect together with the OpenAtlas team. These improvements have taken place, but at a time cost.

The following paragraphs will detail another reason for the lack of a filled OpenAtlas database: the long process of developing a sound metadata schema for physical graffiti and its digital representations.

Graffiti metadata

In addition to the thesaurus, a graffiti metadata schema was developed to capture the relevant information about each graffito (see Figure 3). Metadata, often referred to as 'data about data', provide a detailed description of the physical graffiti and its digital derivatives (like a photograph) to enhance their understanding and interpretation. For example, metadata elements could be the creator and geographical location of the graffito, the approximate moment of graffito production and the materials utilised, the photographer's name and camera model used to take the photo, the graffito's surface area and dominant colour.

A metadata schema is a structured framework that outlines which elements must be collected and how they should be formatted and organised. In addition, the structure of the OpenAtlas database largely depends on the metadata schema. A comprehensive and well-thought metadata schema (and database) not only aids in organising and retrieving graffiti facts but also holds the potential to provide valuable insights into the various social, political, cultural and historical aspects of graffiti. The project coordinator thus found it essential to give this metadata schema considerable thought.

In the scope of project INDIGO, the metadata schema development began by analysing the metadata schemata from the Ancient Graffiti Project, Art Crimes, INGRID, Spraycity and consulting specific resources like the Catalogue for Cultural Objects. All schemata were collected and compared in a spreadsheet to gain insights into the information typically recorded about graffiti and cultural objects on the one hand, and the structure and organisation of this information on the other. Additionally, the INDIGO metadata schema was informed by the research questions from different disciplines interested in graffiti. For example, a historian might be interested in the date and location of a graffito, while a linguist would instead focus on the graphemes and language used. Therefore, the metadata schema must accommodate a wide range of information to cater to these diverse research interests.

Based on these requirements, a first metadata schema was created (see Figure 28). Nevertheless, this was just a schema for the physical graffito. Just like "A map is not the territory it represents, but, if correct, it has a similar structure to the territory, which accounts for its usefulness" (Korzybski, 1933) p. 58, a photograph of a graffito is not the graffito, but a surrogate which can be analogue, digitised or digital-borne. And just like different maps may represent different characteristics of the natural world (e.g. road maps, nautical maps, topographical maps), different surrogates like photos, sketches, and digital 3D surface models can be used to boil down all the complexity of a graffito to those aspects that are needed for a particular purpose or in a specific situation.

INDIGO metadata (physical graffito)

Category Level	Category Name
1	**Descriptive metadata**
1.1	Core metadata
1.2	Locational metadata
1.3	Temporal metadata
1.4	Contentual / aboutness metadata
1.5	Formal / appearance metadata
2	**Administrative metadata**
2.1	Rights metadata
2.2	Access metadata
2.3	Technical metadata
3	**Structural metadata**
3.1	Origin relationships
3.2	Graffiti ensemble relationships
3.2	Spatio-temporal relationships

Figure 28 – The two category levels of INDIGO's first metadata schema to describe a physical graffito.

In project INDIGO, all these graffito surrogates or graffito representations are digital-born. Even though none of these digital representations is the physical graffito, they allow us to obtain data and information about the real graffito. Since the real graffito and the digital representations are separate entities – denoted data, subject or (information) resources in information science jargon – they obtain their own metadata in

project INDIGO regarding the metadata elements and their values. For example: "camera model" is an irrelevant metadata element for the real graffito; "author" and "copyright" are elements relevant for both but populated with different, resource-dependent values. Any non-ambiguous metadata schema should reflect this distinction.

Even though the Cataloging Cultural Objects guidelines called for separating physical and electronic resources in 2006, metadata for cultural heritage assets typically still ignore this distinction. INDIGO made the distinctiveness of these resources explicit. Since there should also only be one metadata record for a single resource (known as the One-to-One Principle in information science), one metadata record per physical graffito and one for each digital resource (e.g., a geometry-corrected digital photograph of the graffito or a 3D surface model extracted from those photographs) was the correct way to proceed.

Most of these concepts and ideas only formed throughout project INDIGO, so their complexity was underestimated. However, like the other more theoretical aspects of INDIGO, the amount of time devoted to thinking and discussing these topics resulted in a unique and sound basis upon which others can build. In that way, the results are currently less tangible than initially hoped for, but the future relevance might be more significant. Finally, one must know that the metadata schema is one of the few INDIGO outputs that are not yet publicly accessible because it was not tested enough in various circumstances.

Objectify graffiti

Throughout the project, it became apparent how inconsistent graffiti terminology is used and how ambiguous graffiti styles are described. If scholars ever want to compare their research and start linking databases, there is not only a need for common terminology (which is why INDIGO developed a graffiti thesaurus; see Section A1-WP13) but also for a less subjective graffiti classification. In this regard, the work of Lisa Gottlieb needs to be mentioned. In her 2008 book *Graffiti art styles: A classification system and theoretical analysis*, Gottlieb introduced a graffiti style classification system based on so-called 'defining properties'. Each style can also have specific 'predominant' and 'other' properties, but they do not 'define' the style.

The INDIGO team found this idea very powerful, which led to two derivates:

- First, a small Gottlieb Styles Visualiser (GSV) program was developed to visualise Gottlieb's system, hopefully making it easier to grasp and play around with (see Figure 31). The GSV is freely downloadable from INDIGO's GitHub.
- Second, the team organised various brainstorming sessions to check if similar approaches could define (and thereby 'objectify') graffiti types and classes. Although there was not enough time at the end of the project (mainly due to the logistics for the goINDIGO 2023 symposium and its proceedings; see Section A1-WP18), it is certainly an avenue that should be considered for future research. For example: 'mural' is equally common used as a graffito type, class or style. However, all three are distinct concepts, so 'objectifying graffiti descriptions' boils down to semantics, good structure and unambiguous definitions, the same principles governing the INDIGO thesaurus.

Honesty demands to say that many of these lacunes in scholarly graffiti work were only picked up while actively working on the spatial database and trying to be consistent. This oversight is the responsibility of the project coordinator. Despite all the background reading while writing the project proposal, entering a new field of research will likely always bring such omissions along.
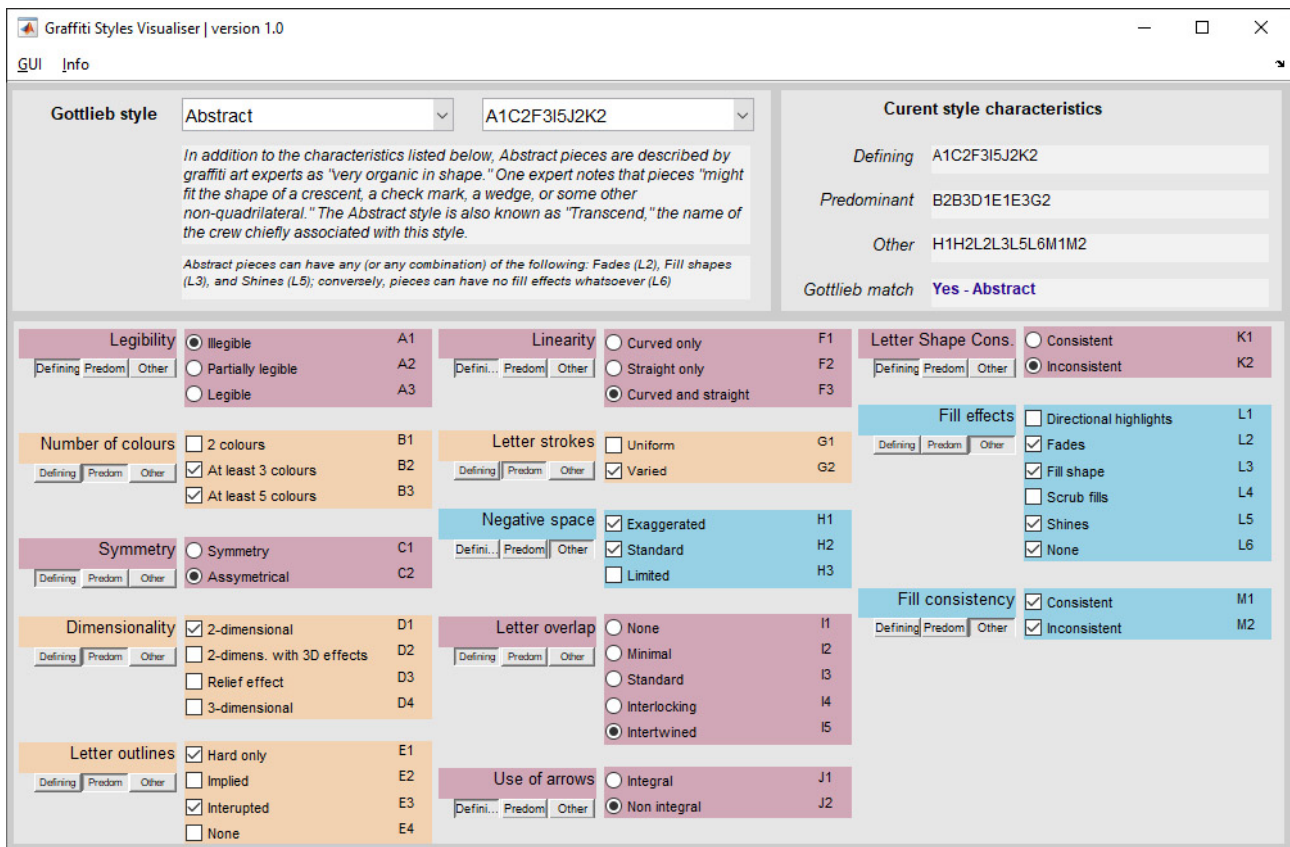
Figure 29 – A screenshot of the GSV.

WP 15 – Data ingestion

INDIGO data are not only ingested in OpenAtlas (for clarity covered mainly in the previous WP) but also in ARCHE, the certified repository of the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH). At the ACDH-CH, discussions have occurred on how OpenAtlas data should flow to ARCHE (to minimise manual work) and vice versa. The details of all these improvements are covered in the upcoming paper *The Data Crew - Archive with ARCHE and enrich with OpenAtlas* (see Section A3). As part of the ingestion discussion, INDIGO has also settled for an "In Copyright" statement for all its photographs (see Table 1). Section 1A-WP1 described how ARCHE will – for now – mainly store INDIGO's primary input data. More specifically, this means (see also Figure 30):

- **Image data**: **431k photos,** of which 247k photos are unique:
  - 184k photos result from the two Nikon Z7ii cameras. These images represent the raw camera data, saved as *.NEF with an *.XMP sidecar file. Both files are combined into one *.DNG file for storage in ARCHE. Since the *.DNGs represent raw camera data, they cannot be anonymised. Therefore, these files will feature restricted access.
  - The same 184k photos also have an in-camera generated *.JPG variant. All these Jpegs get anonymised with the Celantur software and will be freely available.
  - INDIGO's GoPro cameras generated 63k photos. Since these only come in a *.JPG version, they will be freely available as anonymised images.
- **Positional data**: **155** text-based log files from the Solmeta GMAX GNSS (Global Navigation Satellite System) receiver Solmeta and INDIGO's bespoke RTK-GNSS solution (see Section A1-WP6). Besides these original files, there will also be a *.GeoJSON variant with extra metadata, making for **310** files.

- **Spectrometer data**: **3493** *.CSV files and a *.JSON variant with more metadata, totalling almost **7k** files.

			Instrument	Subfolder count	File count	JPG count	DNG count	Size JPG	Size DNG (estimated)
Primary 01-Input	Image data	Stills	GooglePixel6Pro	1	11	11		55.09 MB	
			GoProHERO10Black-A	14	26282	26281	1	65.85 GB	18 MB
			GoProHERO10Black-B	12	20826	20826		52.35 GB	
			GoProHERO11Black	11	16510	16510		48.62 GB	
			NikonD750	8	27906	13932	13974	253.34 GB	0.81 TB
			NikonZ7ii-A	31	133113	66664	66449	2.00 TB	6.98 TB
			NikonZ7ii-B	104	206250	103125	103125	3.04 TB	10.76 TB
			Total	**181**	**430,898**	**247,349**	**183,549**	**5.45 TB**	**18.55 TB**
			Instrument	Subfolder count	File count	TXT/LOG count	GeoJSON count	Size TXT/LOG	Size GeoJSON (estimated)
	Positional data		RTKGNSS-A	0	36	18	18	25 MB	50 MB
			RTKGNSS-B	0	74	37	37	40 MB	10 MB
			SolmetaGMAX-A	0	68	34	34	48 MB	12 MB
			SolmetaGMAX-B	0	132	66	66	16 MB	4 MB
			Total	**0**	**310**	**155**	**155**	**129 MB**	**76 MB**
			Instrument	Subfolder count	File count	CSV count	GeoJSON count	Size CSV	Size JSON (estimated)
	Spectrometer data		SekonicC7000-A	0	390	195	195	4 MB	6 MB
			SekonicC7000-B	0	6,596	3,298	3,298	63 MB	95 MB
			Total	**0**	**6,986**	**3,493**	**3,493**	**67 MB**	**101 MB**

Figure 30 – An overview of all Primary research data ARCHE will store.

Over time, all primary INDIGO input data will be downloadable here: https://hdl.handle.net/21.11115/0000-0011-0DC7-F. Currently (October 2023), data cleaning and anonymisation are still ongoing. When that process has finished entirely, data ingestion in ARCHE can start. Due to the massive dataset size and the metadata that will be provided for (and, where applicable, also embedded within) each file, the finalisation of this process is foreseen around the end of December 2023.

Throughout the project, INDIGO's graffiti overview photographs were also integrated into the Spraycity archive. As agreed, project INDIGO gets credited (see an example here). In this way, INDIGO supported the local and twenty-year-old graffiti database curated by Spraycity (a vital INDIGO partner).

WP 16 – Online platform

The open-access online platform is where all WPs should have culminated. Textured 3D views should allow visitors to look at present-day graffiti in their geographically correct urban setting, scroll through time, and visually experience the works' time span. A section to browse through detailed graffiti orthophotographs plus functions to download and extensively query (meta)data should also be present.

Even though the INDIGO team has worked towards that goal during the two project years, producing this platform's data and underlying technologies has proved more demanding than initially thought. Overall, the project took the following approach to the platform:

- All basic building blocks for the platform – like the thesaurus, the metadata schema and the spatial-temporal reasoning – received due attention, as these are helpful research outputs for other scholars. The thesaurus is discussed in Section A1-WP13, but there is, for example, no WP for the spatio-temporal reasoning. It only became apparent during the project that no out-of-the-box solution exists for this critical aspect, so the team had to devote much initially unplanned research to this aspect (see below). Ultimately, this was very helpful as it also helped improve the spatial database's structure (see Section A1-WP14).

- Generating graffiti records and implementing them in OpenAtlas (the spatial database that should feed all info into the online platform) received less attention because there is no use in having many records with sub-par documentation. There are enough sub-optimal graffiti databases, so there is no need for another one. Data should only get imported in OpenAtlas once the underlying metadata schema and database model are robust and flexible enough to handle the queries mentioned above. Otherwise, the INDIGO would only create a sub-optimal, sub-par result that would die off soon.
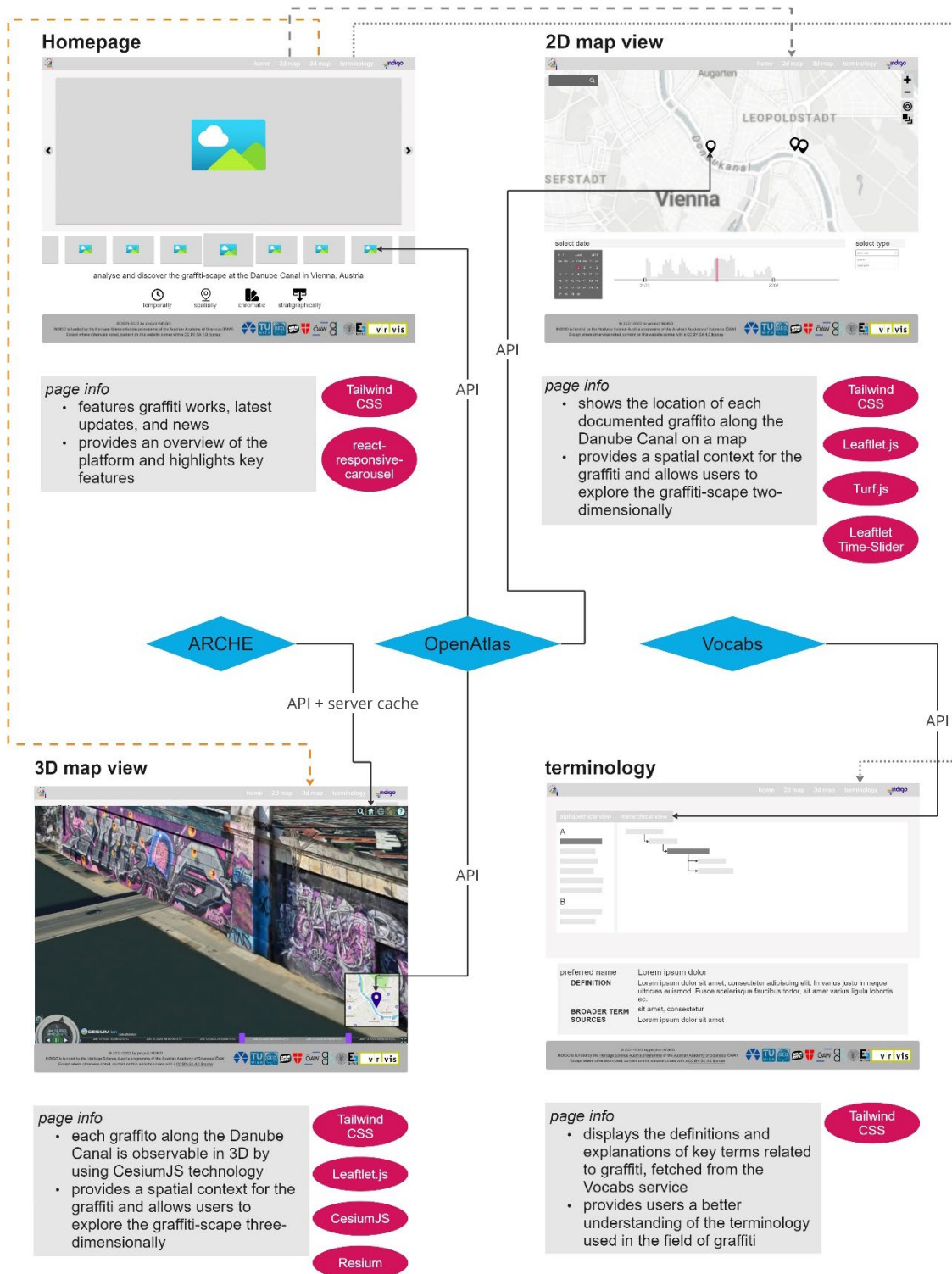

Figure 31 – Wireframe of UrbanChameleon showing the data input (blue diamonds) and dependencies (pink ellipses) for every page. Figure by Jona Schlegel.

- The platform already has a name and URL: **UrbanChameleon** @ https://www.urbanchameleon.eu.
- The structure of UrbanChameleon ensures that most necessary technologies are in place (like data fetching via specific APIs; see Figure 31) to end up with a working platform once final graffiti records become present in OpenAtlas (which will hopefully happen in a follow-up project).
- The platform (i.e., all its currently used and unused functionality) consists entirely of open-source components, and all source code is available online. Various technologies were explored in the first project year, and the team settled for CesiumJS, an open-source and JavaScript-based geospatial library to work online with virtual globes and 3D maps. Besides conventional 2D maps, UrbanChameleon aims to offer visitors a digital 3D surface model of the entire Donaukanal. Whereas this surface model digitally represents the geometry of the graffiti-scape, all documented graffiti should be visualised via time-dependent texturing of this geometry. In that way, UrbanChameleon hopes to facilitate virtual graffiti-scape walks through space and time. CesiumJS was chosen to make this entire experience responsive and realistic. Besides CesiumJS, many other Web technologies already found their way into UrbanChameleon. Table 1 summarises them, and Figure 31 indicates them where it is relevant. The INDIGO team hopes this technological stack can one day facilitate a large, interactive online environment that allows one to query and download the underlying database of graffiti records on the one hand, and show those graffiti in a spatially and temporally accurate virtual context on the other. In that way, the online platform might enable a more comprehensive understanding and appreciation of graffiti as a form of cultural heritage.

Table 2 – This table summarises the programming languages, libraries (collections of pre-written code used for common tasks), and frameworks (structures dictating the architecture of the software) utilised for INDIGO's UrbanChameleon platform. Besides a description, each technology's benefits, limitations, selection rationale, and specific role are outlined.

Component	Type	Description	Benefits	Limitations	Choice Motive	Implementation
HTML	Markup Language	Creates web pages	Universal, easy to use, supported by all browsers	Limited to static pages	Foundation of web pages	Structures web content
CSS	Style-Sheet Language	Styles HTML documents	Design flexibility, separates content from design	Requires understanding of inheritance and overriding	Controls layout of web pages	Styles HTML elements
SCSS	Preprocessor	Extends CSS, adds features	Variables, nesting, mixins	Requires a build step	Enhances CSS functionality	Generates final CSS
JavaScript	Programming Language	Enables interactive web pages	Interactivity, rich interfaces, versatility	Browser compatibility issues	Makes web pages dynamic	Handles form validation, data processing
React	Library	Builds user interfaces	Component-based, fast rendering, SEO-friendly	Requires in-depth JavaScript knowledge	Develops complex UIs	Builds the user interface
TypeScript	Language	JavaScript Superset, aadds static types	Error detection, enhances code readability	Requires compilation	Enhances code reliability	Writes main application logic
Next.js 13	Framework	Enables server-side rendering, generates static websites	Performance benefits, fast refresh, data fetching	Requires React knowledge	Improves performance	Structures the web application
CesiumJS	Library	Creates 3D globes and maps	High-precision rendering, feature-rich	Requires suitable hardware, up-to-date browser	Represents geographical context	Creates 3D globes and maps
Resium	Library	CesiumJS wrapper, used with React	Simplifies use of CesiumJS with React	Limited community, relies on CesiumJS	Facilitates use of CesiumJS	Integrates CesiumJS into the application
Potree	Library	Renders large point	Handles large data, open-	Requires suitable hardware	3D environment	Renders large point

		clouds in the browser	source		representation	clouds
Leaflet	Library	Creates mobile-friendly interactive maps	Easy to use, high performance, cross-platform	Requires plugins for advanced features	Lightweight, efficient	Implements interactive maps
Leaflet Time Slider	Library	Time slider plugin for Leaflet	Temporal-based filtering and visualisation	Requires time-based data	Enables temporal control map data	Controls display of time-based data

WP 17 – Symposium 1

Project INDIGO has planned two workshops (covered by this and the following WP). The first workshop in May 2022 was called goINDIGO 2022 and tackled all aspects of documenting, archiving and disseminating graffiti-scapes. Section A6 provides all relevant information on this workshop.

WP 18 – Symposium 2

The second INDIGO symposium – goINDIGO 2023 – took place from Wednesday, the 14th of June, until Friday, the 16th (see again Section A6 for more info). Most of the goINDIGO 2022 ingredients – such as the symposium location, the layout for the programme and book of abstracts, and the catering – remained unchanged to minimise organisational efforts. Nevertheless, the project coordinator underestimated the number of person-hours that went into organising both symposia (and the proceedings afterwards). Although there was a clear strategy behind the inclusion of two symposia (one to get familiar with common problems and another to disseminate INDIGO's results), in hindsight, the burden on the team and the research programme was too much. Luckily, all the team efforts paid off in terms of publications and project awareness, but they caused delays in other WPs.

WP 19 – Fundraising

Project INDIGO has laid the foundations for what hopefully will continue in various follow-up INDIGO projects (INDIGO 2.0, INDIGO 3.0). However, if INDIGO is to document and analyse a decade of graffiti, avoiding data acquisition gaps is vital. In Augustus 2023, the project coordinator found a way to financially compensate Stefan Wogrin until at least 31/01/2024 for his weekly photography tours of new graffiti.

By mid-November 2023, the project coordinator will also apply for a Cesium Ecosystem Grant. The proposal is currently (i.e., October 2023) prepared and aims to fund INDIGO project member Jona Schlegel for one year to research – and implement – a way to deal with temporally-bound textures for a large 3D model of the Danaukanal. This spatio-temporal visualisation of a graffiti-scape was one of the prime aims of INDIGO. However, it is easier said than done and necessitates researching and developing various components. Since INDIGO's UrbanChameleon platform already has established the necessary code blocks to use Cesium's 3D visualisation technology, this grant could help solve one of the critical components towards an online, interactive and compelling spatio-temporal visualisation of thousands of graffiti.

Third, the project coordinator aims to write an application for Kulturerbe digital (Eng. Cultural heritage digital), a funding programme supporting digital technology to make Austria's cultural heritage more usable and accessible to an (inter)national public. In the future, other project calls will also be checked and proposals written, not only because this is a requirement at the project coordinator's new job (i.e., senior scientist at the University of Vienna) but because of the desire to fund a follow-up INDIGO 2.0 project.

2. Status Work Plan (according to the time line in the proposal)

The initial GANTT chart of project INDIGO is displayed below (Figure 32). Every WP is depicted and colour-coded according to the five research pillars outlined at the beginning of Section A1:

- Pillar A: Acquisition
- Pillar B: Processing
- Pillar C: Management
- Pillar D: Dissemination
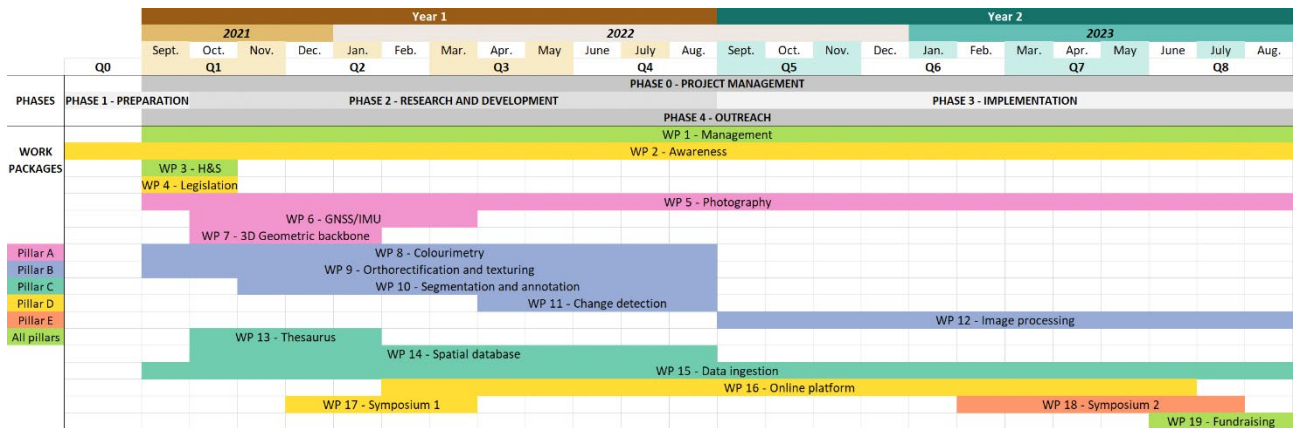- Pillar E: Analysis

Figure 32 – Initial INDIGO GANTT chart.

Figure 33 visualises the new time plan made at the start of project year 2. In addition, the GANTT chart also depicts the renewed milestones set by project INDIGO one year ago. The latter are sorted in various ways in the lower part of Figure 33.
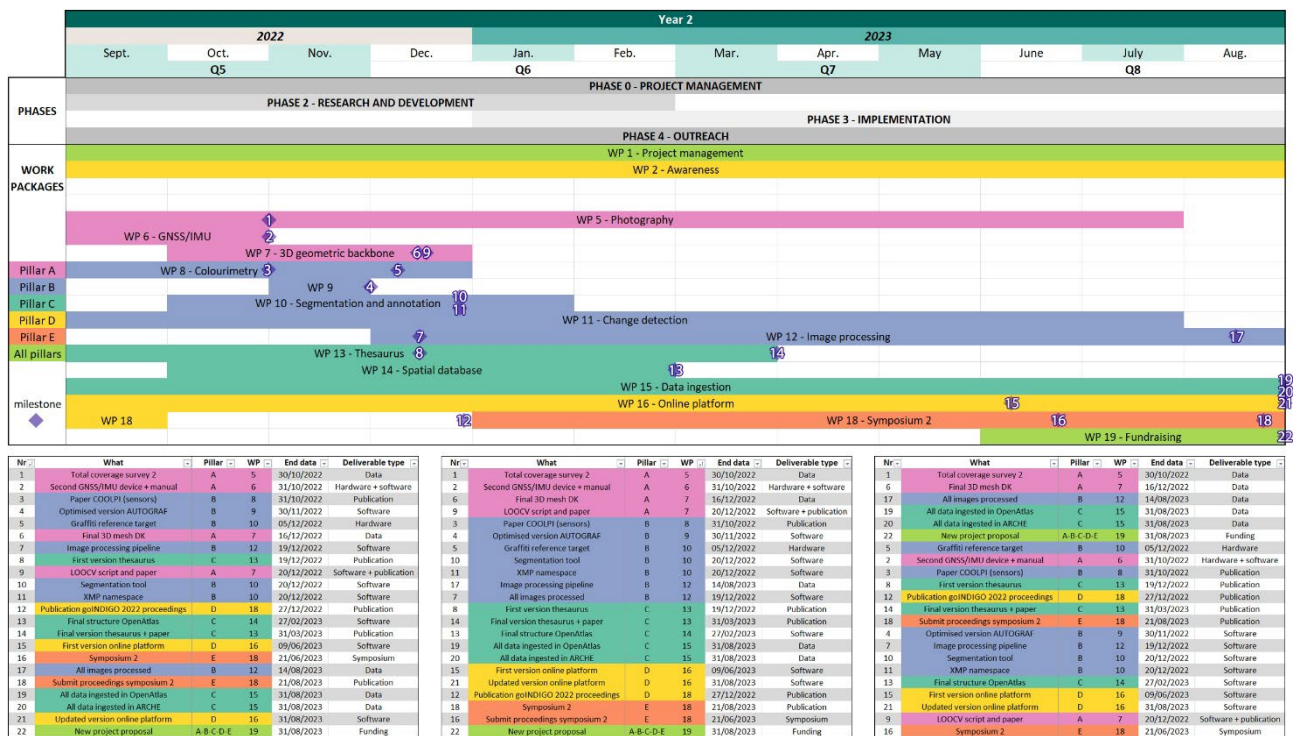

Figure 33 – On top: the GANTT chart for project INDIGO's second year, with all milestones indicated. Below, all milestones are sorted by milestone number, WP, and deliverable type.
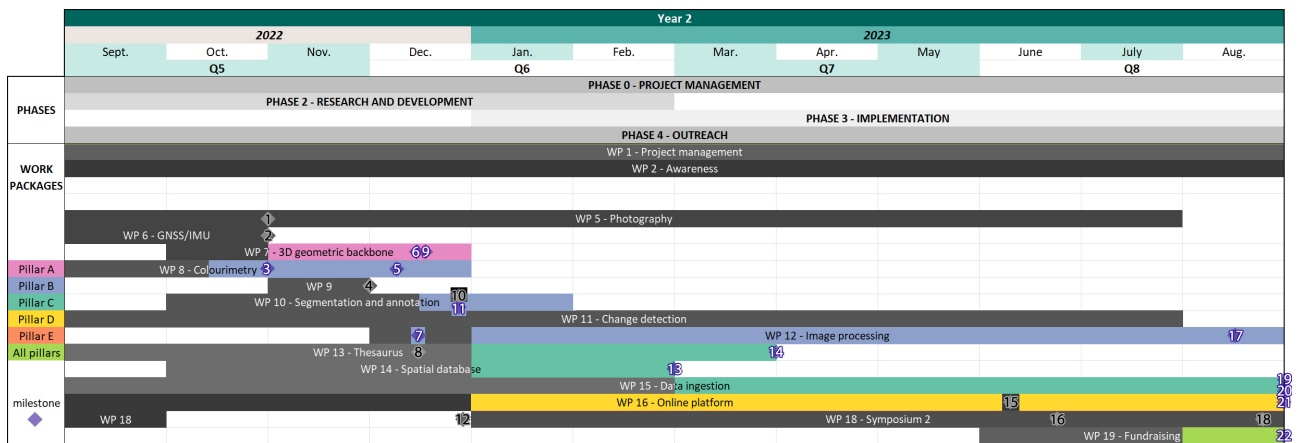
Figure 34 – The INDIGO GANTT chart at the end of the project. Greyed-out milestones were achieved, while WPs were greyed out according to progress.

Figure 34 displays INDIGO's progress after year two. WPs 3 and 4 no longer appear in this chart because they were finished in year one already. The remaining WPs are greyed out according to the progress made. For instance, WP 1, WP 2, WP 5, WP 6, WP 9, WP 11, and WP 18 have fulfilled all the goals. Other WPs like 7, 12, 15 and 16 did not, due to the various reasons explained in this report. To name just two: the very time-consuming organisation of the goINDIGO symposia with their proceedings and the unanticipated large amount of work to properly structure the field of graffiti in a thesaurus and metadata schema. The latter is a typical low-visibility product with little academic credit despite the large amount of research that underpins it.

What is also impossible to get from this GANTT chart are the many papers, presentations, databases and software packages INDIGO produced. All these are detailed in the next section.

3. Publications

INDIGO is an open-data and open-access project operating according to the [FAIR principles](#). Whereas the project's primary research data are available via the [ARCHE data repository](#), all other scientific output (which were stored in the Supplementary directory; see Section A1-[WP1](#)) can be found at different locations:

- INDIGO's [Zenodo community](#)
- INDIGO's [project website](#)
- INDIGO's [GitHub](#)
- The [TU Wien Research Data repository](#)

On the first two locations – and the websites of the respective publishing houses – one will find the **four** peer-reviewed journal papers, **one** edited proceedings volume and **nine** conference papers. In addition, **one** peer-reviewed paper, **one** edited proceedings volume and **five** conference papers have been submitted.

The edited conference proceedings are a tangible result of INDIGO's goINDIGO symposia. Publishing these proceedings has been a priority from the project's start for two primary reasons. First, they illustrate the status quo of many graffiti research domains, turning them into a reference point for future research. As such, the proceedings help achieve greater awareness for INDIGO. Second, the proceedings allow the publication of research-in-progress, negative results, thought processes and experimental papers, most of which are very hard to disseminate via the standard publication channels. For instance, two papers in the goINDIGO 2022 proceedings are edited reflections of the dedicated discussion sessions between academics and graffiti creators. Other papers provide the entire reasoning behind the thesaurus structure or the photo acquisition strategy. This makes the research processes and decisions within INDIGO explicit and provides practical advice for other researchers. Despite their non-peer-reviewed nature, the project coordinator ensured that all INDIGO proceedings papers upheld the same academic standards (in language, referencing and structure) expected of high-level scholarly journals. The editors of the proceedings also tried to achieve that for all non-INDIGO contributions. This turned out to be a new experience for many contributors, leading to much more editorial work than anticipated.

Below, all publications are listed (also those currently submitted). In addition to these 'conventional' publications, project INDIGO also published open-source and freely available software code, an open-source framework for a graffiti dissemination platform, graffiti literature and terminology databases, two thesauri and a change detection benchmark dataset in the past two years. These types of 'publications' are enumerated as well.

Peer-reviewed journal papers (4 + 1)

1. Nocerino, E., Menna, F., Verhoeven, G.J., 2022. *Good vibrations? How image stabilisation influences photogrammetry*. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLVI-2/W1-2022, 395–400. DOI: [10.5194/isprs-archives-XLVI-2-W1-2022-395-2022](#)

2. Verhoeven, G.J., Wild, B., Schlegel, J., Wieser, M., Pfeifer, N., Wogrin, S., Eysn, L., Carloni, M., Koschiček-Krombholz, B., Molada-Tebar, A., Otepka-Schremmer, J., Ressl, C., Trognitz, M., Watzinger, A., 2022. *Project INDIGO – document, disseminate & analyse a graffiti-scape*. ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVI-2/W1-2022, 513–520. DOI: [10.5194/isprs-archives-XLVI-2-W1-2022-513-2022](#)

   This article won the **best paper award** at the **3D-ARCH 2022 conference**. More info on this award is available [here](#).

3. Wild, B., Verhoeven, G., Muszyński, R., Pfeifer, N. 2023. *An automated, hybrid change detection framework for graffiti*. The Photogrammetric Record. Submitted.

4. Wild, B., Verhoeven, G., Pfeifer, N. 2023. *Tracking the urban chameleon – Towards a hybrid change detection of graffiti*. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, X-M-1-2023, 285–292. DOI: 10.5194/isprs-annals-X-M-1-2023-285-2023

5. Wild, B., Verhoeven, G.J., Wieser, M., Ressl, C., Schlegel, J., Wogrin, S., Otepka-Schremmer, J., & Pfeifer, N., 2022. *AUTOGRAF—Automated Orthorectification of GRAFfiti Photos*. Heritage, 5(4), 2987–3009. DOI: 10.3390/heritage5040155

> This article was the **Heritage cover story** in December 2022 (see the archived webpage or Figure 19).

Edited proceedings volume (1 + 1)

1. Verhoeven, G.J., Schlegel, J., Wild, B., Wogrin, S., Carloni, M. (Eds.), 2022. *document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium*. Urban Creativity, Lisbon. ISBN: 979-8394601279

2. Verhoeven, G.J., Schlegel, J., Wild, B., Wogrin (Eds.), 2023. *disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium*. Urban Creativity, Lisbon. Submitted.

Conference papers (9 + 5)

1. Carloni, M., Verhoeven, G.J., Schlegel, J., Wogrin, S., 2023. *The challenges of preservation: Digitizing graffiti in the urban landscape*, in: La memoria digitale: Forme del testo e organizzazione della conoscenza. Atti del XII Convegno Annuale AIUCD (AIUCD 2023), Siena, Italy, 5-7 June 2023. Associazione per l'Informatica Umanistica e la Cultura Digitale, pp. 338-342. DOI: 10.5281/zenodo.8004645

2. Merrill, S., Verhoeven, G.J., Wild, B., JANER ONE, MANUEL SKIRL, SERT, SNUF, Carloni, M., de la Iglesia, M., Fernandez Merino, F., Radošević, L., Ricci, C., Schlegel, J., Wogrin, S., 2023. *'Different folks, different strokes': goINDIGO 2022's «Creators vs Academics» discussion round*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 25-44. DOI: 10.48619/indigo.v0i0.701

3. Molada-Tebar, A., Verhoeven, G.J., 2023. *Towards colour-accurate documentation of anonymous expressions*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 86-130. DOI: 10.48619/indigo.v0i0.704

4. Schlegel, J., Carloni, M., Wogrin, S., Verhoeven, G.J., 2022. *Making a mark—Towards a graffiti thesaurus*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 203-219. DOI: 10.48619/indigo.v0i0.710

5. Schlegel, J., Wieser, M., Verhoeven, G.J., 2023. *Getting Hold of the Urban Chameleon—Towards a Platform for Graffiti Visualisation and Analysis*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

6. Trognitz, M., Carloni, M., Koschiček-Krombholz, B., 2023. *The Data Crew - Archive with ARCHE and enrich with OpenAtlas*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

7. Verhoeven, G.J., Carloni, M., Schlegel, J., Wild, B., Wogrin, S., 2022. *Finding listeners for walls that speak*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 6-15. DOI: 10.48619/indigo.v0i0.699

8. Verhoeven, G.J., Schlegel, J., Wild, B., 2023. *Each graffito deserves its polygon–It is about time*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

9. Verhoeven, G.J., Schlegel, J., Wild, B., Wogrin, S., 2023. *The world as a convas*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

10. Verhoeven, G.J., Wieser, M., Carloni, M., 2023. *GRAPHIS—Visualise, Draw, Annotate, and Save Image Regions in Graffiti Photos*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

11. Verhoeven, G.J., Wogrin, S., Schlegel, J., Wieser, M., Wild, B., 2022. *Facing a chameleon—How project INDIGO discovers and records new graffiti*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 63-85. DOI: 10.48619/indigo.v0i0.703

12. Wild, B., Verhoeven, G.J., Pfeifer, N., Bonadio, E., DEADBEAT HERO, FUNKY, JANER ONE, MANUEL SKIRL, Carloni, M., Ricci, C., Koblitz, C., Niemann, S., Radošević, L., Schlegel, J., Watzinger, A., Wogrin, S., 2022. *'Imagine being a racist': goINDIGO 2022's «Ethics & legality in graffiti (research)» discussion round*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 45-62. DOI: 10.48619/indigo.v0i0.702

13. Wild, B., Verhoeven, G.J., Wieser, M., Ressl, C., Otepka-Schremmer, J., Pfeifer, N., 2023. *Graffiti-Dokumentation: Projekt INDIGO*, in: 22. Internationale Geodätische Woche Obergurgl 2023, Obergurgl, Austria. 12-18 February 2023. Wichmann, Berlin, pp. 322–325. DOI: 10.5281/zenodo.7715655

14. Wild, B., Verhoeven, G.J., Wogrin, S., Wieser, M., Otepka-Schremmer, J., Pfeifer, N., 2022. *Urban Creativity meets Engineering. Automated Graffiti Mapping along Vienna's Donaukanal*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 131-145. DOI: 10.48619/indigo.v0i0.705

The INDIGO team also created three software packages (AUTOGRAF, COOLPI and GRAPHIS) besides a handful of smaller scripts, the basics for the online graffiti dissemination platform UrbanChameleon and a GUI (Graphical User Interface) to visualise graffiti-style categories. The source code of all these developments is open-source and freely downloadable from INDIGO's GitHub account.

Software packages (3 + 1)

1. **AUTOGRAF** (**AUT**omated **O**rthorectification of **GRAF**fiti photos) is an open-source Python-based Metashape add-on enabling automated orthorectification of graffiti photos. The source code can be found here. The principles of this software have been published in:

   o Wild, B., Verhoeven, G.J., Wieser, M., Ressl, C., Schlegel, J., Wogrin, S., Otepka-Schremmer, J., & Pfeifer, N., 2022. *AUTOGRAF—Automated Orthorectification of GRAFfiti Photos*. Heritage, 5(4), 2987–3009. DOI: 10.3390/heritage5040155

   o Wild, B., Verhoeven, G.J., Wieser, M., Ressl, C., Otepka-Schremmer, J., Pfeifer, N., 2023. *Graffiti-Dokumentation: Projekt INDIGO*, in: 22. Internationale Geodätische Woche Obergurgl 2023, Obergurgl, Austria. 12-18 February 2023. Wichmann, Berlin, pp. 322–325. DOI: 10.5281/zenodo.7715655

   o Wild, B., Verhoeven, G.J., Wogrin, S., Wieser, M., Otepka-Schremmer, J., Pfeifer, N., 2022. *Urban Creativity meets Engineering. Automated Graffiti Mapping along Vienna's Donaukanal*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022

       international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 131-145. DOI: 10.48619/indigo.v0i0.705

2. **COOLPI** (**CO**lour **O**perations **L**ibrary for **P**rocessing **I**mages) is an open-source Python toolbox that includes procedures for the colour correction of RAW photos. The code resides here, while an extensive user manual is available at https://graffitiprojectindigo.github.io/COOLPI. This software has been detailed in:

     o   Molada-Tebar, A., Verhoeven, G.J., 2023. *Towards colour-accurate documentation of anonymous expressions*, in: document | archive | disseminate graffiti-scapes. Proceedings of the goINDIGO2022 international graffiti symposium, Vienna, Austria, 11-13 May 2022. Urban Creativity, Lisbon, pp. 86-130. DOI: 10.48619/indigo.v0i0.704

3. **GRAPHIS** (**G**enerate **R**egions and **A**nnotations for **P**hotos using the **IPTC** **S**tandard) is an open-source Python-based software to create, visualise and annotate image regions and store them inside the image metadata according to the IPTC photo metadata standard. The source code is available here. This paper that covers this software has been submitted for publication:

     o   Verhoeven, G.J., Wieser, M., Carloni, M., 2023. *GRAPHIS—Visualise, Draw, Annotate, and Save Image Regions in Graffiti Photos*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

These three software packages also feature a logo following the INDIGO colour scheme and indicating the speed-oriented (AUTOGRAF), histogram-oriented (COOLPI) and polygon-oriented (GRAPHIS) nature of that software (Figure 35).

Figure 35 – The AUTOGRAF, COOLPI and GRAPHIS logos.

One software package is still in development and, hence, not shared yet. The project coordinator intends to finish this software in 2024 while occupying his new position as a senior scientist at the University of Vienna.

4. **POLYGRAF** keeps track of a graffito's relevant spatio-temporal properties (tied to a graffito-specific polygon), similar to a polygraph recording stress indicators during an interview. The principles of

POLYGRAF (and the entire spatio-temporal reasoning on which it is based) can be found in a submitted paper:

- o Verhoeven, G.J., Schlegel, J., Wild, B., 2023. *Each graffito deserves its polygon–It is about time*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

Figure 36 – The POLYGRAF logo.

Online platform

INDIGO's UrbanChameleon platform should culminate all project efforts and give users a distinctive perspective on the graffiti-scape along Vienna's Donaukanal. Although the platform is live, there is not much to see yet. Nevertheless, the entire framework is open source and shared via GitHub. For further details, kindly check the following paper:

Schlegel, J., Wieser, M., Verhoeven, G.J., 2023. *Getting Hold of the Urban Chameleon—Towards a Platform for Graffiti Visualisation and Analysis*, in: disseminate | analyse | understand graffiti-scapes. Proceedings of the goINDIGO2023 international graffiti symposium, Vienna, Austria. 14-16 June 2023. Urban Creativity, Lisbon. Submitted.

Figure 37 – The logo of INDIGO's UrbanChameleon platform.

Graffiti styles visualiser

In her 2008 book *Graffiti art styles: A classification system and theoretical analysis*, Lisa Gottlieb presented a system to define various graffiti styles adequately. Project INDIGO supports Gottlieb's approach, as it seems a solid way to 'objectify' graffiti categorisation. INDIGO developed the Gottlieb Styles Visualiser or GSV, a small MATLAB program that tries to make Gottlieb's approach more tangible and visually clear.

MATLAB Medley

Various MATLAB-based scripts were programmed to clean, harmonise and convert the spectrometer files, the photos' metadata and the logs of the GNSS receivers. Although these pre-processing scripts do not come with a GUI and much of their code is INDIGO-specific, they were grouped in a so-called MATLAB Medley repository and shared online.

Datasets: Databases (2) | Thesauri (2) | Image collections (2)

INDIGO wanted to create the foundations for prolonged graffiti documentation, dissemination and analyses. That is why the project proposal also expressed the wish for INDIGO to slowly turn into an international graffiti knowledge hub. Various datasets were made freely available to help achieve this: two databases, two thesauri, and two image collections.

1. **INDIGO Graffiti Literature Database**. During the project, all INDIGO relevant literature was collected in a closed-source [Citavi](#) and an open-source [Zotero](#) database. Since both databases contained many references on topics that are not per se graffiti-related (like colourimetry, semantic technologies, copyright law and spatio-temporal reasoning), a slimmed-down 'graffiti only' version of those databases was shared publicly, featuring almost 1250 references. These **INDIGO Graffiti Literature Databases** also excluded PDFs to avoid possible copyright infringements. The open-source Zotero database can be accessed [via this link](#). The data-sharing platform Zenodo also offers an *.RDF and *.BIB (i.e., BibTex) variant of this database (DOI: [10.5281/zenodo.8393824](#)) for import into other reference managers. This DOI also features the *.CTV6ARCHIVE file that can be opened in the closed-source but powerful Citavi database software.

2. **INDIGO Graffiti Terminology Database**. In the existing body of popular and scholarly graffiti literature, many attempts have been made to describe or structure graffiti-related terminology. The **INDIGO Graffiti Terminology Database** (DOI: [10.5281/zenodo.8419328](#)) collects graffiti-related terms and their definitions as they appear in the glossaries, dictionaries and various controlled vocabularies consulted within project INDIGO (for the exact meaning of "thesaurus", "glossary", and "controlled vocabulary", please consult [INDIGO's paper](#) on this topic). This dataset currently holds 2134 entries extracted from 48 multi-lingual sources. Each of those entries is a concept with a definition and some metadata like the language of the concept/definition and the source. Version 1.0 of this Graffiti Terminology Database features 1728 terms in English, 303 in German, 61 in French and 42 in Italian. This resource has been essential in shaping INDIGO's Graffiti Thesaurus (see point 3 below). Although this dataset is currently distributed as two 'flat' files, future expanded versions will also be incorporated into an [SQLite database](#) to enable easier interaction with – and control of – all the data, thereby turning it into an actual database.

In addition to both databases, two thesauri are freely accessible online. In contrast to the two databases that consolidate scattered graffiti-relevant literature and terminology into one file, thesauri are semantic tools that can – when agreed upon – form the terminological and hierarchical backbone of a research field.

3. **INDIGO Graffiti Thesaurus**. This thesaurus (see Section A1-[WP 13](#), or consult it [here](#)) is a curated academic resource centred on contemporary graffiti terminology, with a spatial focus on Vienna's Danube Canal. It is a compilation of terms that organises, categorises, and connects graffiti-related concepts through equivalence, hierarchical, and associative relationships. INDIGO has devoted significant research to creating this thesaurus of 179 graffiti concepts and ensuring it is embeddable into the [Getty AAT](#), the world's most popular heritage thesaurus. Despite that effort, no concept definitions are currently (i.e., October 2023) present since time failed to define all 179 terms consistently and exhaustively. However, the project coordinator intends to continue working on these definitions, aided by the Graffiti Terminology Database explained in point 2.

4. **GRAPHIS Image Region Thesaurus**. This controlled vocabulary (consult it [here](#)) of eight terms contains all the concepts used by INDIGO's bespoke image segmentation tool GRAPHIS to annotate image regions (see Section A1-[WP10](#) or [here](#)). Image regions are shapes like circles, rectangles or any possible polygon that can be marked and saved within an image. The [IPTC Photo Metadata Standard](#) has enabled storing these [image regions](#) since its [2019.1 version](#). GRAPHIS (Generate Regions and Annotations for Photos using the IPTC Standard) provides a graphical user interface to

generate, visualise and annotate these image regions while adhering to the IPTC Photo Metadata Standard.

Finally, INDIGO also made two large image sets available.

5. **INDIGO Photographs**. All 247k unique photographs resulting from the Total Coverage, Follow-Up and Change Detection tours will be freely available in the [ARCHE repository](#) by the end of 2023. Each photograph will feature a consistent metadata record and be anonymised; most photographs will also have geographical coordinates. Raw camera data in the form of *.DNG files will also be available for 184k out of these 247k photos. Since it is impossible to anonymise these files, their access will be severely restricted. However, non-commercial research projects can apply for access to those photographs.

6. **INDIGO Change Detection Reference Dataset**. When developing change detection algorithms, the INDIGO team decided a reference would be needed to compare the effectiveness of its bespoke approaches (see Section 1A-[WP11](#) for all details). This view has materialised in a large reference dataset, accessible via the relatively new TU Wien data repository; DOI: [10.48436/ayj4e-v4864](#). This set of manually and semi-automatically created synthetic photos, masks, and change maps can be used by other scholars to benchmark image change detection algorithms. The dataset also adheres to the IPTC Photo Metadata Standard. Each of the 20,742 images has specific licensing information embedded, a short image description, and the image creator.

4. Collaborations

Industry

When considering collaborations that were not already mentioned in the project proposal, INDIGO could secure two alliances with partners from the industry:

- With **EPOSA** or Echtzeit Positionierung Austria, a technological leader in satellite-based positioning in Austria. EPOSA enables real-time correction of positional data from the Beidou (China), GALILEO (Europe), GLONASS (Russia) and GPS (USA) satellite constellations. Thanks to EPOSA's head of service Dipl.-Ing. Christian Klug, INDIGO could use the EPOSA correction signal freely.
- With **Celantur**, a Linz-based company specialising in anonymising still images and videos. The software blurs faces and can automatically anonymise entire bodies. Thanks to Alexander Petkov, CEO at Celantur, INDIGO could successfully test the software on a series of project photos. Afterwards, Celantur and INDIGO reached a mutually beneficial agreement to use the software for the anonymisation of all project photographs.

There was also an essential information exchange with some key players in the photographic industry (but INDIGO did not receive any products or services):

- The developers of **Camera Bits** and **Photools**. These companies build the photo management systems Photo Mechanic Plus and IMatch, respectively. INDIGO used both packages, as they respect almost all metadata standards and guidelines established by various organisations (like IPTC and Adobe).
- **David Riecks**, co-lead of the IPTC Photo Metadata Working Group.

Non-profit

INDIGO collaborated with **Street Art Belgrade** (SAB). During the goINDIGO 2023 symposium, Ljiljana Radošević from SAB asked if INDIGO staff could support them with their photographic documentation and photogrammetric processing. That is why Benjamin Wild went to Belgrade from the 21st to the 27th of September, 2023. This stay included two full days of photography and a small workshop, after which the resulting 3D models and videos of all documented graffiti were provided to SAB. During a meeting with the *Österreichisches Kulturforum Belgrad* (Eng. Austrian Culture Forum Belgrade), the plan arose to organise a graffiti documentation workshop in 2024 so that more INDIGO core members could partake.

Academia

General

On the academic side, collaborations were established with:

- Assistant Professor **Ann Graf** from the School of Library and Information Science at Simmons University (USA). Prof. Graf's research on organising and describing graffiti terms was especially relevant for INDIGO. That is why she co-authored INDIGO's paper on the graffiti thesaurus.
- **TU Vienna's Pilot Research Ethics Committee** (see Section A1-WP 4 for more details).
- **the Image Processing and Interpretation (IPI) group at Ghent University**. Rafał Muszyński, a PhD student at IPI, collaborated for a few months on INDIGO's change detection (during a less busy period in his PhD). As a result, Rafał is a co-author on INDIGO's last change detection paper and the change detection reference dataset, detailed in Section 1A-WP14.

Theses | exercises (4)

Several students used INDIGO material for a variety of academic purposes:

1. Bachelor thesis
   - Study: **Bachelor Programme Geodesy and Geoinformation (033 221) – TU Wien**
   - Student: Martin Rachbauer
   - Period: 02-2022 to 12-2022
   - Title: *Analyse verschiedener Methoden zur Graffiti Segmentierung*
   - Supervisor: Benjamin Wild
2. Master thesis
   - Study: **Master programme Geodesy and Geoinformation (066 421) – TU Wien**
   - Student: Oskar Baumann
   - Period: 12-2022 to 09-2023
   - Title: *Mapping Street Art: Developing Cartographic Visualisation of Graffiti*
   - Supervisor: Benjamin Wild
   - URL: https://oacbaumann.github.io/graffiti_map
3. Master thesis
   - Study: **Master programme Data Science (066 645) – TU Wien**
   - Student: Fabian Dachs
   - Period: 11-2022 to 11-2023
   - Title: *Change Detection in Graffiti Images*
   - Supervisor: Sebastian Zambanini
4. Exercises
   - Study: **Master programme Geodesy and Geoinformation (066 421) – TU Wien**
   - *Course: Location Based Services*
   - Students: Benjamin Stifter, Olivia Panzenböck & Lena Wohlgenannt
   - Period: 03-2023 to 07-2023
   - URL: https://lbs-project-group1.netlify.app/index.html

5. Conferences and workshops attended

INDIGO staff has attended a wide variety of national and international gatherings. In the following list, internal workshops at the host and participating institutes have been omitted. Some conferences or workshops at the end of this list took place (or are planned to occur) after project INDIGO finished. However, they are listed because INDIGO made them possible.

1. 30/04/2021 [Online]
   a. Workshop: **Using Vocabularies and Linked data: #ConnectingArchaeology webinar**
   b. Attendee: *Geert Verhoeven*
   c. Remark: this workshop took place before the INDIGO project started, but many INDIGO-specific questions were asked.
2. 17/09/2021 [Vienna, Austria]
   a. Conference: **Second Heritage Science Austria Meeting**
   b. Attendee: *Geert Verhoeven*
3. 19/11/2021 [Online]
   a. Meeting: **Meeting Ethical Commission TU Wien**
   b. Attendees: *Norbert Pfeifer, Geert Verhoeven, Benjamin Wild*
4. 17/01/2022 [Online]
   a. Workshop: **SynerGIS After Business Workshop, topic "SURE"**
   b. Attendee: *Jona Schlegel*
5. 02/03/2022 [Mantova, Italy]
   a. Conference: **3D-ARCH'2022 - 3D Virtual Reconstruction and Visualisation of Complex Architectures – 9th International Workshop**
   b. Attendee: *Benjamin Wild*
6. 31/03/2022 [Online]
   a. Workshop: **Pointcloud Workshop of the Geospatial Research Innovation Development lab at the University of New South Wales**
   b. Attendee: *Benjamin Wild*
7. 11-13/05/2022 [Vienna, Austria]
   a. Symposium: **goINDIGO 2022: document | archive | disseminate graffiti-scapes**
   b. Attendees: *entire INDIGO team*
8. 15/06/2022 [Online]
   a. Workshop: **ARIADNEplus workshop: Semantic mapping of excavation data**
   b. Attendees: *Jona Schegel, Geert Verhoeven*
9. 20-24/06/2022 [Prato, Italy]
   a. Summer school: **ARIADNEplus Summer School: Mapping Existing Datasets to CIDOC CRM**
   b. Attendee: *Jona Schegel*
10. 23/09/2022 [Vienna, Austria]
    a. Conference: **Third Heritage Science Austria Meeting**
    b. Attendees: *Geert Verhoeven, Benjamin Wild*
11. 12-18/02/2023 [Obergurgl, Austria]
    a. Conference: **22. Internationale Geodätische Woche Obergurgl 2023**
    b. Attendee: *Benjamin Wild*
12. 23/02/2023 [Online]
    a. Workshop: **Discover Graffiti mit INGRID**
    b. Atendees: *Jona Schlegel, Geert Verhoeven, Stefan Wogrin*
13. 17-19/04/2023 [Krems, Austria]
    a. Symposium: **DigiKult 2023**
    b. Attendees: *Jona Schlegel, Geert Verhoeven*

14. 05-07/06/2023 [Siena, Italy]
    a. Conference: **La memoria digitale: Forme del testo e organizzazione della conoscenza. Convegno Annuale AIUCD (AIUCD 2023)**
    b. Attendee: *Massimiliano Carloni*
15. 14-16/06/2023 [Vienna, Austria]
    a. Symposium: **goINDIGO 2023: disseminate | analyse | understand graffiti-scapes**
    b. Attendees: *entire INDIGO team*
16. 25-30/06/2023 [Florence, Italy]
    a. Conference: **CIPA 2023: Documenting, Understanding, Preserving Cultural Heritage: Humanities and Digital Technologies for Shaping the Future**
    b. Attendee: *Benjamin Wild*
17. 07/07/2023 [Online]
    a. Conference: **Urban Creativity Conference 2023: Numbers**
    b. Attendee: *Geert Verhoeven*
18. 27-29/09/2023 [Hamburg, Germany]
    a. Conference: **Studying Written Artefacts: Challenges and Perspectives**
    b. Attendee: *Jona Schlegel*
    c. Remark: this conference takes place after the INDIGO project, but we were invited thanks to our work in INDIGO.
19. 24-25/10/2023 [Vienna, Austria]
    a. Conference: **Cultural Heritage-Research in the Digital Age**
    b. Attendees: *Massimiliano Carloni, Bernhard Koschiček-Krombholz, Martina Trognitz, Alexander Watzinger*
    c. Remark: this conference takes place after the INDIGO project.
20. 08-09/12/2023 [Karlsruhe, Germany]
    a. Workshop: **Onsite – On surface – Online: Entanglements between Locations and Processes in Graffiti Practices**
    b. Attendees: *Massimiliano Carloni, Jona Schlegel, Benjamin Wild*
    c. Remark: this workshop takes place after the INDIGO project, but we were invited thanks to our work in INDIGO.
21. 09-11/09/2024 [Vienna, Austria]
    a. Conference: **European Cartographic Conference – EuroCarto 2024**
    b. Attendees: *Geert Verhoeven, Stefan Wogrin, Benjamin Wild*
    c. Remark: this conference takes place after the INDIGO project, but we were invited thanks to our work in INDIGO.

6. Organised workshops

Because INDIGO has a technical- and more humanistic-oriented aspect, both facets were planned to be covered by two symposia. Although COVID-19 was still wreaking havoc across the world in 2022, the hope was nurtured to physically bring together specific subsections of the (scholarly) graffiti community in Vienna. The initial timing of both symposia was deliberate and tried to maximise the relevancy of the discussions and insights gained for the INDIGO team (see also Figure 38).
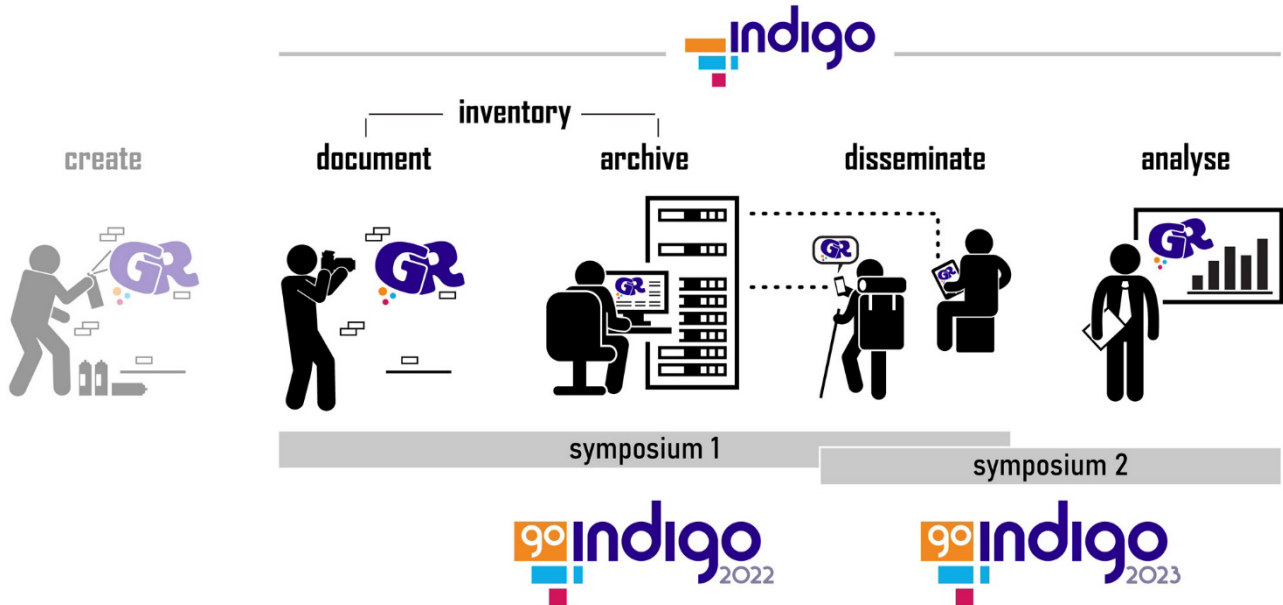

Figure 38 – The main goals of project INDIGO and how they fit within the two goINDIGO symposia.

- **goINDIGO2022** was planned to take place six months into the project and tackle all the technical, logistic, legal, and ethical aspects of documenting, archiving, and disseminating graffiti. The idea of gathering experts and experience so early was to help avoid pitfalls on various more technical topics further down INDIGO's road.
- A second symposium – **goINDIGO 2023** – was scheduled for the end of the project. This gathering should focus on graffiti's socio-political and cultural impact. goINDIGO 2023 would also mark the launch of INDIGO's online platform and showcase how its stored graffiti (meta)data enables societal and cultural insights. In this way, specialists in art history, philosophy, cultural studies, law, urbanism, psychology, and communication would see the potential of this massive open-access archive, thereby ensuring this project's transdisciplinary sustainability.

goINDIGO 2022

Although the uncertainty created by the COVID-19 pandemic slightly delayed the goINDIGO 2022 symposium and made a hybrid event inevitable, INDIGO managed a small but successful gathering. From the 11th to the 13th of May 2022, a mixed group of sixty participants (graffiti creators, heritage professionals and graffiti academics) from twelve countries met in Vienna or online to learn from each other and build proverbial bridges. Throughout two and a half days, two keynote lectures and eighteen presentations touched upon many facets of documenting, archiving and disseminating graffiti records (see also the book of abstracts). The word cloud generated from the goINDIGO 2022 book of abstracts reflects this topical diversity (Figure 39).

Figure 39 – The word cloud extracted from the goINDIGO 2022 book of abstracts.

Still, this word cloud fails to represent the various viewpoints that speakers put forward. Such variety should always be sought after, as robust strategies for inventorying and sharing graffiti records can only be obtained when soft sciences meet hard sciences, legal experts discuss with specialists on ethics, archivists get to know web programmers and… graffitists connect with academics. INDIGO considered these *inter-* and *intra-*project collaborations essential because they hold an unlimited potential to draw inspiration from peers and experts in entirely different domains. That is why the goINDIGO 2022 organising team was proud to pull off two highly interactive discussion sessions between those who create graffiti and those who study/archive them. Both discussion sessions were joined by six graffiti creators operating in Vienna.

The proceedings of goINDIGO 2022 were edited by five INDIGO project members and published with Urban Creativity, a household name in graffiti literature and supportive of open access. The final book is available as a freely downloadable PDF or a hard copy. As mentioned in Section A3, these proceedings were also a means to get fresh, often in-progress INDIGO research out. That is why the goINDIGO 2022 volume contains five INDIGO-specific papers.

Even though all goINDIGO 2022 presentations were recorded, they were not shared online. The combination of our recording hardware and the acoustics in the symposium room turned out to be a bad match. However, this experience led to improvements in our audio recording so that all recordings of the goINDIGO 2023 symposium could be digitally shared (see the following paragraphs).

goINDIGO 2023

Slightly over one year after goINDIGO 2022, the INDIGO team organised goINDIGO 2023 from 14-16 June 2023. Because this symposium could build on the success of goINDIGO 2022, all relevant metrics slightly increased: 62 participants from 13 countries and three keynote lectures. These keynotes were absolute highlights of this symposium, as goINDIGO managed to get key figures in the graffiti research field:

- **Brett Webb**: Brett co-founded Art Crimes, the first website to systematically collect and disseminate graffiti photographs. Because all presentations of goINDIGO 2023 have been recorded and published on the INDIGO YouTube channel, the life story of Brett and his pioneering Art Crimes project is now freely available for everybody.
- **Richard van Tiggelen**: With his brother Marcel, Richard founded the Dutch Graffiti Library, a multi-faceted collective aiming to disseminate all aspects of graffiti culture. His keynote is also on the INDIGO YouTube channel, making it the first and only place to hear the entire Dutch Graffiti Library story.
- **Holly Sypniewski**: Holly is co-director of the Ancient Graffiti Project that catalogues all ancient graffiti of Pompeii and Herculaneum. Holly's keynote was essential to raise awareness about the similarity in research methods for ancient and contemporary graffiti and to show how large research databases can be shared online. This keynote cannot be found on YouTube, as recording was not allowed.

Besides the three keynotes, goINDIGO 2023 counted 18 presentations about the dissemination, analyses, and understanding of graffiti-scapes (see the word cloud in Figure 40). Apart from one regular talk and one keynote, all presentations can be rewatched via the goINDIGO 2023 YouTube playlist. The dedicated "graffiti dissemination" discussion session between academics and graffiti creators was also not recorded to respect the anonymity of the latter.

Currently (i.e., October 2023), the goINDIGO 2023 organising team is finalising the proceedings. This volume will be slightly smaller (around 13 contributions) but again freely available via Urban Creativity.

Figure 40 – The word cloud extracted from the goINDIGO 2023 book of abstracts.

7. Scientific Presentations

Below, all twenty-three scientific talks and four posters on INDIGO-specific topics are listed (some of which took place/will take place after project INDIGO). If the presentation is available online, it has gotten a DOI number over Zenodo. As with the publications, all presentations are available on the [Zenodo community webpage](#) and the [project website](#). Some presentations have not been put online (and were not given a DOI), as the slides of those presentations are (almost) identical to those of previous talks.

1. 17/09/2021 [Vienna, Austria]
   a. Conference: **Second Heritage Science Austria Meeting**
   b. Title: *INDIGO: INventory and DIsseminate Graffiti along the dOnaukanal*
   c. Presenter: Geert Verhoeven
   d. Invited: Yes
   e. DOI: [10.5281/zenodo.6338834](#)
2. 19/11/2021 [Online, Austria]
   a. Meeting: **Meeting Ethical Commission TU Wien**
   b. Title: *INDIGO: INventory and DIsseminate Graffiti along the dOnaukanal*
   c. Presenter: Geert Verhoeven
   d. Invited: No
3. 25/11/2021 [Vienna, Austria]
   a. Meeting: **Internal meeting at the PhotoCircle research group (Geodesy Department TU Wien, Austria)**
   b. Title: *Photogrammetry in context of the graffiti-research project INDIGO*
   c. Presenter: Benjamin Wild
   d. Invited: No
4. 02/03/2022 [Mantova, Italy]
   a. Conference: **3D-ARCH'2022 - 3D Virtual Reconstruction and Visualisation of Complex Architectures – 9th International Workshop**
   b. Title: *Project INDIGO – document, disseminate & analyse a graffiti-scape*
   c. Presenter: Benjamin Wild
   d. Invited: No
   e. DOI: [10.5281/zenodo.6339489](#)
5. 03/03/2022 [Mantova, Italy]
   a. Conference: **3D-ARCH'2022 - 3D Virtual Reconstruction and Visualisation of Complex Architectures – 9th International Workshop**
   b. Title: *Good vibrations? How image stabilisation influences photogrammetry*
   c. Presenter: Fabio Menna
   d. Invited: No
   e. DOI: [10.5281/zenodo.6382756](#)
6. 31/03/2022 [Online, Australia]
   a. Workshop: **Pointcloud Workshop (Geospatial Research Innovation Development lab at the University of New South Wales)**
   b. Title: *Project INDIGO - document, disseminate & analyse a graffiti-scape*
   c. Presenter: Benjamin Wild
   d. Invited: Yes

7. 11/05/2022 [Vienna, Austria]
    a. Symposium: **goINDIGO 2022: document | archive | disseminate graffiti-scapes**
    b. Title: *Discovering & recording new graffiti within project INDIGO*
    c. Presenter: Geert Verhoeven
    d. Invited: No
    e. DOI: 10.5281/zenodo.6574796
8. 11/05/2022 [Vienna, Austria]
    a. Symposium: **goINDIGO 2022: document | archive | disseminate graffiti-scapes**
    b. Title: *Achieving colour-accurate data from images: challenges and solutions*
    c. Presenter: Adolfo-Molada Tebar
    d. Invited: No
    e. DOI: 10.5281/zenodo.6579429
9. 12/05/2022 [Vienna, Austria]
    a. Symposium: **goINDIGO 2022: document | archive | disseminate graffiti-scapes**
    b. Title: *Towards a graffiti thesaurus in SKOS*
    c. Presenter: Jona Schlegel & Massimiliano Carloni
    d. Invited: No
    e. DOI: 10.5281/zenodo.6578470
10. 12/05/2022 [Vienna, Austria]
    a. Symposium: **goINDIGO 2022: document | archive | disseminate graffiti-scapes**
    b. Title: *Towards the automatic production of graffiti orthophotos*
    c. Presenter: Benjamin Wild
    d. Invited: No
    e. DOI: 10.5281/zenodo.6574990
11. 07/07/2022 [Wrocław, Poland]
    a. Meeting: **Guest lecture**
    b. Title: *INDIGO - document, disseminate & analyse a graffiti-scape*
    c. Presenter: Norbert Pfeifer
    d. Invited: Yes
12. 23/09/2022 [Vienna, Austria] - poster
    a. Conference: **Third Heritage Science Austria Meeting**
    b. Title: *Acquiring centimetre-accurate camera coordinates in project INDIGO*
    c. Presenter: Geert Verhoeven
    d. Invited: No
    e. DOI: 10.5281/zenodo.7109573
13. 23/09/2022 [Vienna, Austria] - poster
    a. Conference: **Third Heritage Science Austria Meeting**
    b. Title: *How project INDIGO automatically turns graffiti photos into orthophotomaps*
    c. Presenter: Benjamin Wild
    d. Invited: No
    e. DOI: 10.5281/zenodo.7109431
14. 13/10/2022 [Vienna, Austria]
    a. Workshop: **Standortbestimmung Kulturelles Erbe: Herausforderungen und Potenziale**
    b. Title: *Are times a-changing? Contemporary graffiti in cultural heritage*
    c. Presenter: Massimiliano Carloni
    d. Invited: No
    e. DOI: 10.5281/zenodo.8415418
15. 10/11/2022 [Vienna, Austria]
    a. Meeting: **Scientific Advisory Board meeting of the LBI ArchPro**
    b. Title: *Project INDIGO*

    c. Presenter: Geert Verhoeven

    d. Invited: yes

    e. DOI: 10.5281/zenodo.8112446

16. 17/02/2023 [Obergurgl, Austria] - <u>poster</u>

    a. Conference: **22. Internationale Geodätische Woche**

    b. Title: *Graffiti Dokumentation: Projekt INDIGO*

    c. Presenter: Benjamin Wild

    d. Invited: No

    e. DOI: 10.5281/zenodo.7638295

17. 14/06/2023 [Vienna, Austria]

    a. Symposium: **goINDIGO 2023: disseminate | analyse | understand graffiti-scapes**

    b. Title: *Catching the Urban Chameleon*

    c. Presenter: Jona Schlegel

    d. Invited: No

    e. DOI: 10.5281/zenodo.8112788

    f. Recording: https://youtu.be/_aKazGCZzJE

18. 15/06/2023 [Vienna, Austria]

    a. Symposium: **goINDIGO 2023: disseminate | analyse | understand graffiti-scapes**

    b. Title: *Towards an automated detection of changes in the urban chameleon skin*

    c. Presenter: Benjamin Wild

    d. Invited: No

    e. DOI: 10.5281/zenodo.8113135

    f. Recording: https://youtu.be/HQnPgFta65M

19. 15/06/2023 [Vienna, Austria]

    a. Symposium: **goINDIGO 2023: disseminate | analyse | understand graffiti-scapes**

    b. Title: *GRAPHIS—A free tool to save, annotate and visualise regions in graffiti photos*

    c. Presenter: Geert Verhoeven

    d. Invited: No

    e. DOI: 10.5281/zenodo.8106293

    f. Recording: https://youtu.be/dj3JQfVaxdU

20. 16/06/2023 [Vienna, Austria]

    a. Symposium: **goINDIGO 2023: disseminate | analyse | understand graffiti-scapes**

    b. Title: *One polygon at a time – trying to manage a graffiti-scape's spatio-temporality*

    c. Presenter: Geert Verhoeven

    d. Invited: No

    e. DOI: 10.5281/zenodo.8105895

    f. Recording: https://youtu.be/FB3TK432jAU

21. 27/06/2023 [Florence, Italy]

    a. Conference: **CIPA 2023: Documenting, Understanding, Preserving Cultural Heritage: Humanities and Digital Technologies for Shaping the Future**

    b. Title: *Tracking the urban chameleon – towards a hybrid change detection of graffiti*

    c. Presenter: Benjamin Wild

    d. Invited: No

    e. DOI: 10.5281/zenodo.8124248

22. 07/07/2023 [Lisbon, Portugal]

    a. Conference: **Urban Creativity Conference 2023: Numbers**

    b. Title: *Project INDIGO – An overview in numbers*

    c. Presenter: Geert Verhoeven

    d. Invited: Yes

    e. DOI: 10.5281/zenodo.8124879

23. 29/09/2023 [Hamburg, Germany]
    a. Conference: **Studying Written Artefacts: Challenges and Perspectives**
    b. Title: Acquiring, Archiving and Annotating Contemporary Graffiti within project INDIGO
    c. Presenter: Jona Schlegel
    d. Invited: Yes
24. 25/10/2023 [Vienna, Austria] - <u>poster</u>
    a. Conference: **Cultural Heritage-Research in the Digital Age**
    b. Title: *(Digitally) preserving cultural heritage: the example of contemporary graffiti in the project INDIGO*
    c. Presenter: Massimiliano Carloni
    d. Invited: Yes
    e. Remark: this conference takes place after the INDIGO project
25. 08/12/2023 [Karlsruhe, Germany]
    a. Workshop: **Onsite – On surface – Online: Entanglements between Locations and Processes in Graffiti Practices**
    b. Title: *INDIGO and the Graffito: Navigating Definitions and Digital Representations*
    c. Presenter: Jona Schlegel
    d. Invited: Yes
    e. Remark: this workshop takes place after the INDIGO project, but we were invited thanks to our work in INDIGO
26. 08/12/2023 [Karlsruhe, Germany]
    a. Workshop: **Onsite – On surface – Online: Entanglements between Locations and Processes in Graffiti Practices**
    b. Title: *Engineering meets graffiti: How can photogrammetry digitally safeguard the ephemeral?*
    c. Presenter: Benjamin Wild
    d. Invited: Yes
    e. Remark: this workshop takes place after the INDIGO project, but we were invited thanks to our work in INDIGO
27. 08/12/2023 [Karlsruhe, Germany]
    a. Workshop: **Onsite – On surface – Online: Entanglements between Locations and Processes in Graffiti Practices**
    b. Title: *Street Walls to Digital Archives: Preserving? Cultural? Heritage?*
    c. Presenter: Massimiliano Carloni
    d. Invited: Yes
    e. Remark: this workshop takes place after the INDIGO project, but we were invited thanks to our work in INDIGO

8. Visitors

INDIGO did not have official visitors, although several people asked if they could become involved in one way or another. Some of those were among the biggest names in the graffiti scene, like Cassedy Curtis (author of Graffiti Archaeology) and Brett Webb (co-initiator of Art Crimes, which INDIGO managed to invite as a keynote speaker for the goINDIGO 2023 symposium). In other cases, people like Ann Graff were only met digitally and ended up on a publication. However, rather than having visitors, INDIGO visited many other workshops and projects (see Sections A4 and A5).

9. Public dissemination

Website | newsletter | protocols

- From the start, INDIGO shared all relevant information via its frequently updated **project website** at https://projectindigo.eu. A dedicated blog section brought attention to the latest news. Figure 41 displays some statistics about the INDIGO website.
- INDIGO published a bi-weekly newsletter in the first 16 project months. These newsletters – which can be found here – always featured three hyperlinked sections:
    - A short mention of all upcoming meetings.
    - A photograph of a graffito recently created along the Donaukanal. Clicking on this image brought up a map with its location.
    - A short description and link to the **protocol** of past meetings. In that way, the INDIGO meeting protocols were freely accessible to anybody.

    Because of these newsletters' low cost-benefit ratio (i.e., too much work for barely any consultation), the project coordinator decided to cease their creation at the start of 2023.
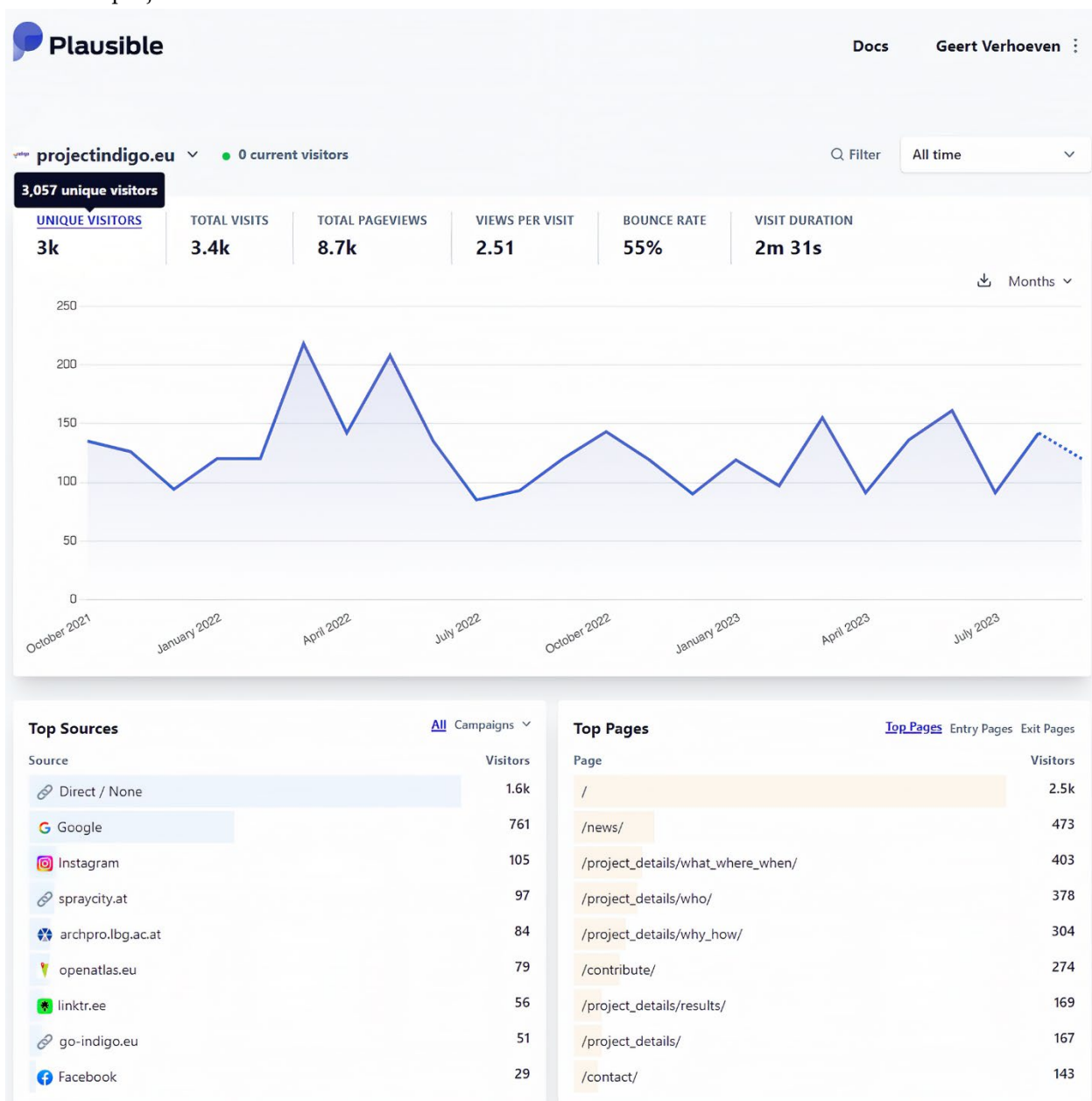
Figure 41 – Some statistics of the INDIGO website since it went live. INDIGO used the open-source, privacy-friendly and GDPR-compliant tool Plausible to collect this information.

Social media

- Project INDIGO had an active **Instagram** account, because it was one of the main platforms where the necessary engagement with graffiti creators occurred. After the first project year, almost 400 people active in the graffiti scene followed INDIGO via Instagram. This engagement was made possible via four types of contributions:
    - Every second Monday, the **Newsletter** was posted.
    - Each Wednesday was **Gallery Wednesday,** and new graffiti creations from the Donaukanal were shared.
    - Every second Friday was **Flashback Friday**: either relevant historical facts on graffiti were shared or a photo composition that compared 2002-2005 versus 2022 photos from the Donaukanal.
    - Every Sunday was **Literature Sunday**, in which literature on graffiti (usually a book) was briefly described.

    Since INDIGO reached a substantial engagement after project year one, the project coordinator decided to devote less time to Instagram and only continue with the Gallery Wednesday posts. Sporadically, other content – like an advertisement for the goINDIGO symposia – was posted. At the end of project year two, INDIGO had circa 500 followers.
- The **Twitter** account of INDIGO was less active, which explains why there are only circa 140 followers as of September 2023. Twitter was mainly used to advertise all the goINDIGO 2022 and 2023 symposia talks.

Press

- On Saturday, the 16th of July 2022, the Austrian newspaper **Die Presse** devoted an article to project INDIGO. The entire article can be found here: https://projectindigo.eu/diepresse
- On Thursday, the 30th of March 2023, the Austrian newspaper Der Standard published an article on INDIGO in their science blog.

The project coordinator also rejected coverage by the ÖRF on the last project day because priority was given to finalising the project and inventorying all data. Once this is taken care of, ÖRF will be contacted again.

Events

- Jona Schlegel and Benjamin Wild presented project INDIGO at the *Lange Nacht der Forschung* (Eng. Long Night of Science) [20/05/2022, Vienna, Austria]). More info and photos of the event are available here.
- Benjamin Wild represented project INDIGO at the **European Researchers' Night** [30/09/2022, Vienna, Austria].
- The Levin Statzer Foundation organised **boat tours** in September and October 2022 along the graffiti-scape of the Donaukanal. During these tours, project INDIGO and its goals were mentioned.
- Benjamin Wild represented project INDIGO at **BEST**, Austria's largest Job, Training and Education fair (Ger. *Beruf Studium Weiterbildung*). More info at https://projectindigo.eu/indigo-at-best.
- Massimiliano Carloni co-organised a graffiti workshop at the **2023 Kinderuni** (Eng. Children's University) event held at the Austrian Academy of Sciences [21/07/2023, Vienna, Austria]. Click here for more info and photos.

Podcasts | interviews

- 31/05/2022: **ILOVEGRAFFITI.DE Podcast 69** featured *Stefan Wogrin* (https://www.youtube.com/watch?v=wf-L2Ysuqn0) talking about INDIGO (40:15 to 46:43).

- 09/05/2022: graffiti creator *Deadbeat Hero* mentions right at the beginning of his **Artcade podcast S08 E01** (https://artcadepodcast.podbean.com/e/s08-e01-ndzw) his partaking in the goINDIGO symposium.
- 04/10/2022: a lengthy interview by CIPA Heritage Documentation with the project coordinator (published on LinkedIn) also touches upon project INDIGO.
- 24/04/2023: an interview with Stefan Wogrin plays at the Bezirksmuseum in the 20th district in an exhibition about the Donaukanal (September-October 2023). Stefan mentioned project INDIGO.

Blog posts

- 05/07/2022: on **theworldinpointclouds**, INDIGO is featured in a blog post on point cloud generation.
- 21/08/2023: the photogrammetric goals of INDIGO are covered in the news section of the **TU Wien website**.
- 22/08/2023: a post on **VRVis homepage** covers the visualisation aspects within INDIGO.
- 22/08/2023: the German website **GEObranchen** covers the 3D modelling aspect of INDIGO (this is a repost of the TU Wien news entry).

10. Group Members (Personnel Recruiting)

During the first year, there were two replacements. Although these people were not recruited per se, they constitute a change in INDIGO staff:

- MSc Ana-Maria Loghin (°1989) was initially planned to take care of the photogrammetric work but had found another job before INDIGO started. Her spot was filled by MSc Benjamin Wild (°1996);
- MS Martin Trognitz (°1986) went on maternity leave in February 2022. Instead, Dr Massimiliano Carloni (°1990) took over her place within INDIGO.

Two people also joined INDIGO on the ACDH-CH side. Both helped with specific aspects of the OpenAtlas software:

- MSc Bernhard Koschicek-Krombholz (°1987) was on the INDIGO payroll and responsible for the API of OpenAtlas.
- BSc Nina Richards (°1983) is not on the INDIGO payroll. Still, she joined the team meetings for her knowledge of the CRM ontology, which partly forms the basis for OpenAtlas. Because INDIGO wants to expand the CRM ontology within OpenAtlas, Nina's input was important.

INDIGO also was actively collaborating with Bachelor and Master students, as its enormous and varied collection of photos is ideal for developing computer vision and cartographic approaches, enabling students from these disciplines to push the boundaries in automated graffiti reading, change detection and visualisation. Since none of these students was on INDIGO's payroll, their contributions are detailed in Section A4 on collaborations.

11. Organisational work

Project INDIGO officially started with a kick-off meeting on the 9th (whole day) and 10th (half a day) of September 2021 (see Figure 42). After everybody introduced themselves in the morning session of the 9th, the team discussed the research and organisational challenges of the upcoming year. In the afternoon, all INDIGO staff (some with their family) participated in a guided tour along the graffiti of the Donaukanal. A graffiti spraying workshop the following morning ensured that all project members could start the project with at least a basic understanding and feeling for spraying graffiti.

Figure 42 – INDIGO's kick-off leaflet.

After the kick-off meeting, a tradition was established to have a team meeting at the end of every month. This practice continued until the end of the project. In addition, a status quo meeting occurred in October 2022 (see Figure 43). The idea of this status quo meaning was two-fold: in the first part, INDIGO's past achievements were presented. These first two hours of the meeting were also streamed online, allowing any interested party to follow the progress made in the first project year. During the second part, the team internally discussed the research plan for year two.

Figure 43 – INDIGO's status quo meeting leaflet.

For day-to-day management, INDIGO's teamwork was founded on four management pillars:

- Daily communication did not run over email but on the Mattermost platform. Mattermost is an online, open-source chat service with file sharing and search options. The service was hosted at the ACDH-CH and could be accessed via a browser or dedicated app on the phone or computer. INDIGO's Mattermost server enabled all staff members to communicate quickly on all relevant topics. This approach also made it easy to include students or researchers who joined INDIGO along the way. Each WP got its Mattermost channel (see Figure 44), and project members could access specific or all channels. In addition, there was a "General" channel for messages that concerned everybody, a "Graffiti Fun" channel for fun facts, and a "Mum, look what I have done channel" (see Figure 44). The idea of the latter channel was to post small snippets of progress (a newly made illustration, some code that got debugged or a paper submission). The project coordinator hoped to keep the team motivated by continuously sharing small pieces of progress. However, some people felt uncomfortable doing this, which led to the implementation of weekly "status quos" (see below).
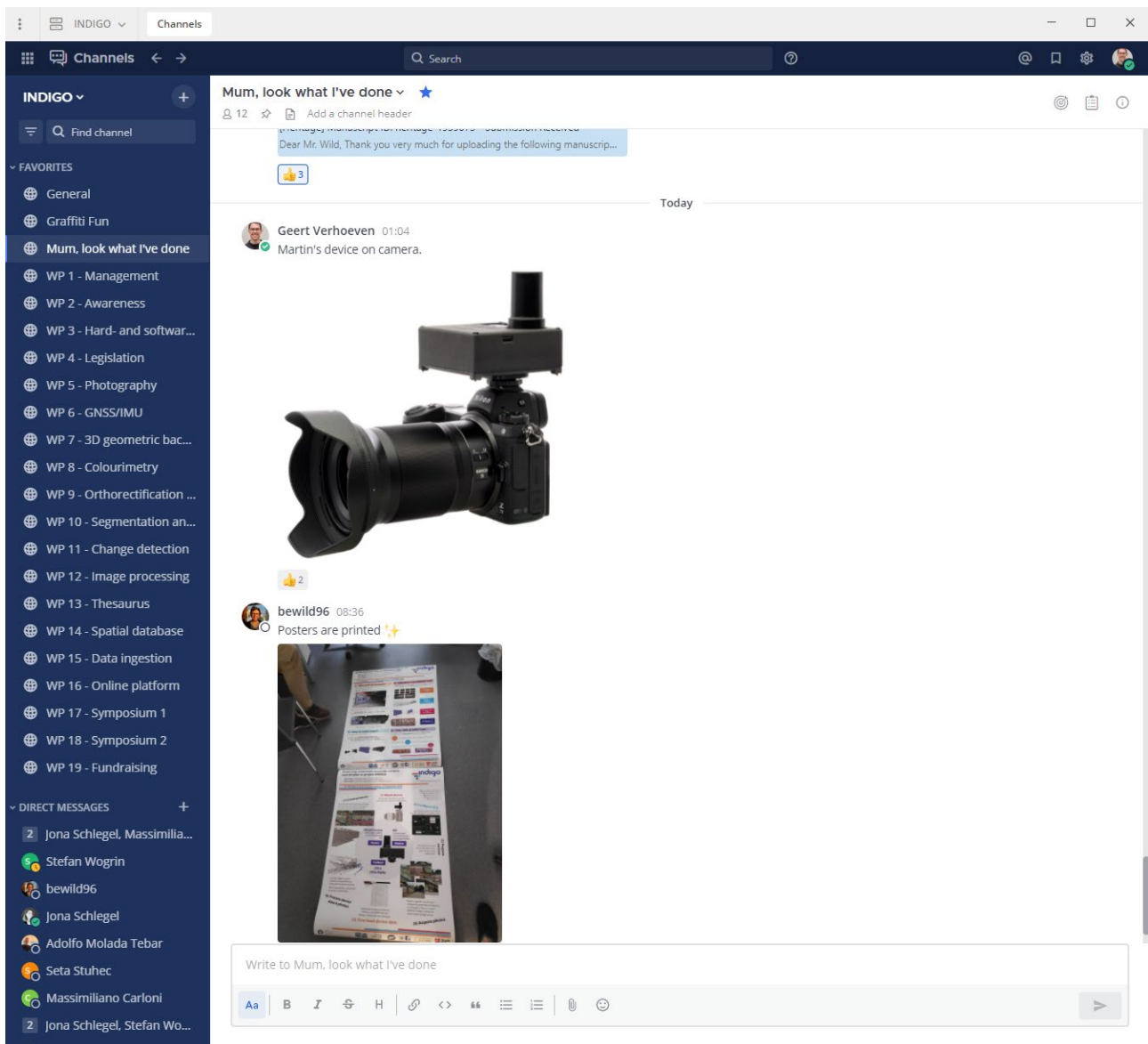
Figure 44 – INDIGO's Mattermost server interface, showing the WP-based organisation on the left, above the direct messages. The screenshot shows some examples of little progress shared in the "Mum, look what I've done" channel.

- The general INDIGO team meeting took place once per month (usually scheduled on that month's last Friday). All running and upcoming research matters, finances, and logistics were discussed during this meeting. Every team meeting came with a detailed agenda and ended with a written protocol. All these meeting protocols are freely accessible.
- Project INDIGO had a Google account, from which mostly the Calendar and Drive functions were used. All INDIGO-relevant appointments and deadlines were stored in the Google calendar to which all team members had access. The same was true for all relevant supplementary INDIGO data (like spreadsheets, scientific papers, flowcharts, and meeting protocols). Using the GDrive technology, everybody had 24/7 access to all these files wherever they worked. INDIGO's GDrive also featured a private section for accounting spreadsheets. Finally, collaboration on scientific articles ran over Google Docs and Sheets.
- The fourth pillar of the management system was Teamwork, a dedicated project management software in which the project leader kept track of the entire research programme and all deliverables. Teamwork was slowly abandoned during project year two, as maintaining the software became challenging to fit between all other activities.

Besides these four pillars, INDIGO also relied on many smaller collaborative tools. One was [MIRO](#), a whiteboard platform used for drafting the thesaurus and metadata schema (see Section A1-[WP13](#)). Another tool that played an essential role in project INDIGO was [sync.com](#). Sync.com ensured that all primary data were safely and quickly stored on INDIGO's central workstation (see Section A1-[WP1](#)).

An agenda was created and shared for every meeting, and almost every meeting resulted in a protocol, even though fewer protocols were written in the last project months due to time constraints. These protocols were shared via the INDIGO newsletter (see also Section A1-[WP2](#)), but one can also consult them [here](#). The protocols also reveal that some meetings occurred before INDIGO's official start in September 2021. Those meetings aimed to align expectations among project partners and ensured INDIGO could hit the ground running on 01-09-2021.

At the start of year two, the coordinator proposed a few specific changes to improve the overall project management and meeting effectiveness.

- **A DRI per deliverable**. Every project deliverable was given a "Directly Responsible Individual" or DRI. Although these people were already appointed in the project's management software Teamwork (see above), this role was never given explicitly. The DRIs were free to decide how to achieve the predefined goal(s), which meant that each DRI needed to take up that responsibility.
- **Weekly status quo**. DRIs were asked to post the status quo of their respective WP at the end of the week on Mattermost. That way, the team could easily follow where problems occurred or how things progressed.
- **Smaller, shorter and more goal-oriented meetings**. All experts and scientific literature make clear that meetings should typically not be attended by more than 4-6 people. Brainstorming with 20+ people is useless. The agreed-on duration sweet spot for most meeting types is 45 minutes. Everything over 1 hour is a no-go because people lose focus and drive (although some meetings can sin against this rule; see below). To help achieve this, the project coordinator wanted every meeting organiser to announce the planned meeting type, its specific goal and duration. That is why four meeting types were established.
  - <u>Informational</u>: a meeting to announce something or keep the team updated. INDIGO team meetings were like this. The purpose was to ensure everyone was on the same page, even though certain group decisions could be made. Although a team meeting should ideally not break the one-hour rule, concise presentations on a deliverable were acceptable. DRIs were asked to provide an overall status quo on their deliverable(s) to break the monologues of the project coordinator.
  - <u>Decision-making</u>: these meetings were about determining what actions everyone needs to take. Such meetings needed small groups. These could last longer, as they usually came with much discussion. Nevertheless, these meetings had to be adequately prepared to minimise their duration.
  - <u>Brainstorming</u>: for creative sessions, all blue skies with no bad ideas. Brainstorming with too many people does not work, so they were limited to 4-6 people and 45 minutes up to a maximum of 1 hour. These meetings were used to make progress on the thesaurus and metadata schema.
  - <u>One-on-one</u>: limited to two people, maximally for 1 hour. However, these were only needed for personal feedback or decision-making that could not take place (or took longer to settle) via Mattermost (see below).

Overall, these measures proved only semi-effective, as they became less strictly followed towards the end of the project.

B. Finances

1. Description of staff and other costs

2. Accounting record

███

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C. Summary/Zusammenfassung

English

Graffiti are studied by archaeologists, sociologists, (art) historians, linguists, ethnographers, anthropologists, librarian scientists, geographers, criminologists, conservators, lawyers and architects (amongst many others). Although most of these professions rely on a digital representation of graffiti at a particular stage of their research, there has been strikingly little attention to how graffiti can effectively be monitored, digitally documented and described. This is precisely one of the gaps the heritage science project INDIGO tried to fill. Through collaboration between geomatics, data management and graffiti specialists, INDIGO developed technical and logistical solutions that facilitate the systematic documentation, monitoring, and analysis of extensive graffiti-scapes, like the one along Vienna's *Donaukanal* (Eng. Danube Canal).

INDIGO's efforts were primarily devoted to research and development, enabling the creation of various products that could benefit the broader heritage science field. From a small device that acquires centimetre-accurate camera coordinates for every photo to freely available software packages that automate the colourimetric and geometric processing of thousands of images. Besides the advancements in spatial database design, graffiti terminology and classification, photo annotation, legislative frameworks, image-based change detection, and photography workflows, INDIGO managed to organise two international goINDIGO graffiti symposia. These expert gatherings functioned as a communication platform for similarly-minded scholars. Simultaneously, they established a bridge between academics and the typically closed community of graffiti creators. Finally, coverage by the press, mentions in podcasts and blog posts, academic and corporate alliances, free access to all software code and data, two dozen scientific talks, various scientific papers (among one award-winning) and two proceedings ensured the project's (inter)national visibility.

Deutsch

Graffiti werden, unter anderen, von ArchäologInnen, SoziologInnen, (Kunst-)HistorikerInnen, LinguistInnen, EthnographInnen, AnthropologInnen, BibliothekswissenschaftlerInnen, GeographInnen, KriminologInnen, RestauratorInnen, Juristinnen und ArchitektInnen untersucht. Obwohl die meisten dieser Berufsgruppen in einem bestimmten Stadium ihrer Forschung auf eine digitale Darstellung von Graffiti angewiesen sind, wurde bisher auffallend wenig darauf geachtet, wie Graffiti effektiv nachverfolgt, digital dokumentiert und beschrieben werden können. Genau diese Lücke sollte das kulturwissenschaftliche Projekt INDIGO schließen. In Zusammenarbeit von Geomatik-, Datenmanagement- und Graffiti-SpezialistInnen entwickelte INDIGO technische und logistische Lösungen, die die systematische Dokumentation, Nachverfolgung und Analyse von großräumigen Graffiti-Landschaften, wie die entlang des Wiener Donaukanals, erleichtern. INDIGO hat in erster Linie Beiträge in Forschung und Entwicklung geleistet und so verschiedene Lösungen geschaffen, die dem breiten Feld der Denkmalpflege zugute kommen: von einem kleinen Gerät, das zentimetergenaue Kamerakoordinaten für jedes Foto erfasst, bis hin zu frei verfügbaren Softwarepaketen, die die farbmetrische bzw. geometrische Verarbeitung tausender Fotos automatisieren. Neben Fortschritten in den Bereichen Datenbankdesign, Graffiti-Terminologie, Beschriftung von Fotos, Rechtsrahmen, bildbasierter Erkennung von Veränderungen und Fotografie-Workflows organisierte INDIGO auch zwei internationale Graffiti-Symposien (goINDIGO 2022 bzw. goINDIGO 2023). Diese Treffen dienten als Kommunikationsplattfrom für gleichgesinnte WissenschafterInnen und bauten gleichzeitig an einer Brücke zwischen Wissenschaft und der typischer Weise geschlossenen Gemeinschaft der Graffiti-MacherInnen. Zusätzlich sorgten die Berichterstattung in der Presse, die Erwähnung in Podcasts und Blogbeiträgen, akademische und unternehmerische Zusammenarbeit, der freie Zugang zum gesamten Softwarecode und zu den Daten, zwei Dutzend wissenschaftliche Vorträge, verschiedene wissenschaftliche Arbeiten und zwei Proceedings für die (inter)nationale Sichtbarkeit des Projekts.

D. Signatures

Principal investigator (Coordinator):

02 / 11 / 2023
_____
(date)

Geert J. Verhoeven
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_____
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For the host institution:

_____
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Elvira Welzig & Marisa Radatz
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