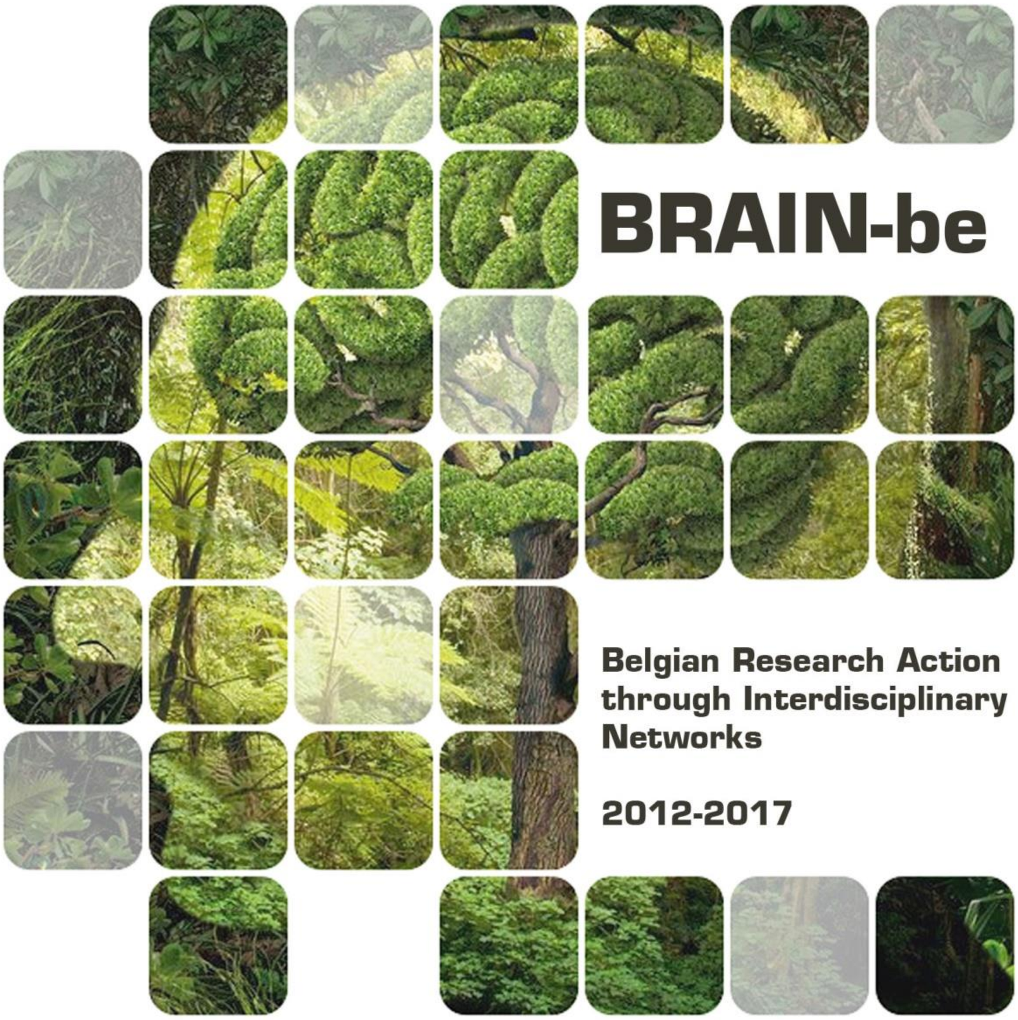

UGESCO

Upscaling the Geo-temporal Enrichment, exploration and exploitation of Scientific COllections

Steven Verstockt (Ghent University – imec, IDLab)

Axis 3: Cultural, historical and scientific heritage

NETWORK PROJECT

UGESCO

Upscaling the Geo-temporal Enrichment, exploration and exploitation of Scientific COllections

Contract - BR/165/A3/UGESCO

FINAL REPORT

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ABSTRACT

Context

The majority of digital collections at the FSIs still have (meta)data issues affecting the exploration, interpretation and exploitation of their content. The coherence between the collection items and their searchability is rather limited, which sometimes makes it difficult to generate scientific/added value out of it. The current metadata scope of the photo archives, for example, is too narrow and too high-level to allow easy and adequate exploration of the collection data.

Objectives

The UGESCO project (Upscaling the Geo-temporal Enrichment, exploration and exploitation of Scientific COllections) developed geo-temporal (meta)data extraction and enrichment tools to extend and link the existing collection items and facilitate spatio-temporal collection mapping for interactive querying. In order to optimize the quality of the temporal and spatial annotations that are retrieved by our automatic extraction/enrichment tools, the UGESCO project also investigated the added value of microtask crowdsourcing in validating and improving the generated metadata. Finally, to ensure optimal exploitation of the generated content, metadata management/filtering techniques were investigated to optimize the quality and usability of all this metadata and geo-temporal mapping services were developed to visualize and query the data in an end user-oriented way. These mappings allow cross-collection analysis in time and space facilitating scientific interpretation of collection items in a broader sense.

Conclusions

Within the context of the interdisciplinary UGESCO project we performed research and development activities in the domain of geographic information retrieval (GIR) and user-generated content (UGC), and investigated how the Belgian Federal CegeSoma collections can benefit from technological innovations in these domains. The proposed generic geo-temporal enrichment framework, however, are widely applicable and our open source building blocks for extraction, enrichment, filtering and mapping of geo-temporal metadata can be reused and extended by all FSIs/federal departments to enrich their data and to facilitate collection access (i.e., to improve the spatio-temporal exploration and linking to other collections).

Keywords

Geographic entity recognition, computer vision, natural language processing, crowdsourcing, user-generated content, metadata enrichment.

1. INTRODUCTION

The UGESCO project investigated the added value of spatio-temporal (meta)data extraction and enrichment with natural language processing and computer vision techniques in the context of FSI collections. The project outcome is a toolbox to automatically improve the metadata quality of collection items. Furthermore, we have built a web-based platform for exploration of the collection (meta)data in time and space. To enhance the exploitation and utilization of collection data in a spatio-temporal way, we also introduced novel interaction mechanisms based on triangular time models and map-centric querying. Providing spatio-temporal querying options to the end user, will help to take away search costs of finding collection items related to a desired place/time and increase the overall user satisfaction.

In addition to the automatic enrichment tools, we also used microtask crowdsourcing to facilitate the annotation process, i.e., to validate the good, the bad and the ugly metadata and to collect missing annotations. The crowd are our collaborative brains that help in enriching the collections, focusing on validation/completion of the time, space and attribute aspects of the collection items.

The technological challenges that were tackled during the project are:

(1) Improving spatio-temporal metadata extraction by textual analysis, e.g., named entity recognition (NER) of geo-locations / timestamps, and image clustering with computer vision techniques, such as convolutional neural networks (CNN) for object class recognition.
(2) To develop crowdsourced microtasks to validate and collect geo-temporal metadata.
(3) To optimize metadata management and filtering, and to provide tools for geo-temporal similarity detection.
(4) Geo-temporal mapping of collection items using geographic information system (GIS) tools and an innovative approach for temporal data exploration based on triangular models.

For each of these challenges, a group of research partners was responsible to create (re)usable interoperable building blocks that can seamlessly interact with each other and the collection data. UGESCO allows collection owners to improve and to promote their content to a broader audience.

<u>Collection focus:</u> In the first place, the UGESCO project mainly focused on the existing collection(s) of CegeSoma, and more specifically its WWII media archives. We introduced extraction, enrichment and mapping tools to facilitate spatio-temporal exploration and linking of the collection items. In addition to these digitalization improvements of the existing collections, we also took advantage of the fact that we are still able to find people who know first-hand WWII stories or who's spatio-temporal reasoning can contribute to our microtask crowdsourcing process for the validation and collection of (meta)data. This valuable crowdsourced data takes the currently available content to a higher level. In order to evaluate the (re)usability of our technologies/platform, we also investigated the feasibility for other/new collections during the project as well (~ EURECA and Flore De Gand project). Multimedia data of the academic heritage archives of UGENT and Stad Gent, for example, were used to evaluate the cross-collection performance and to develop/test tools which could not directly be evaluated on the CegeSoma collections.

2. STATE OF THE ART AND OBJECTIVES

SOTA / OBJECTIVES in natural language processing (NLP) for geo-temporal metadata extraction

Information for enriching electronic data can be found on the Internet, but is not always directly available. NLP techniques, NER, and semantic annotation can be used to automatically enrich textual data, remove disambiguation of named entities, such as timestamps, locations, and names of persons, and deal with uncommon named entities, like locations and persons in the historical context of WW II. In this particular case, it would be useful to create geo-temporal links, whereby, for example, locations mentioned in a text are visualized on a map and can be explored in time. There are a number of enrichment tools available (such as the Stanford Named Entity Recognizer , the AlchemyAPI , the EuropeanaConnect Geoparser , GATE (General Architecture for Text Engineering) , and the enricher engine developed by ITEC and Data Science Lab (Paulussen et al. 2014), but depending on the domain and text type, certain adaptations are required. This may include the adaptation of a gazetteer or the creation of a knowledge base of time-specific entities/relations. An extra challenge consists in analysing textual data describing pictures with reduced syntactic structure (e.g. subject missing, use of infinitives) and lacking co-textual information, as current NLP tools are trained on full sentences text having a verb and subject, requiring specific training and/or adaptation of the NLP tools within the UGESCO project. Since many of the documents produced by the FSI are published in French and Dutch, we also analyzed how similar documents in different languages can be linked.

SOTA / OBJECTIVES in spatio-temporal image clustering (with computer vision techniques)

In addition to the text-based enrichment of the collection metadata, the UGESCO project further improved and extended the geo-temporal metadata by computer vision based clustering of image/video items in time and space. Visual place recognition is a trending topic in computer vision research that tries to detect the location of images or videos without geotags by using primitive plane matching on 2D building outline maps, geolocalization by object recognition or feature matching with georeferenced image datasets. As the first approach has a high computational cost and limited practical applicability, only the latter two approaches are investigated and optimized in this project.

SOTA / OBJECTIVES in microtask crowdsourcing and community building

Crowdsourcing and gamification are techniques that have already caught attention of the cultural heritage sector for various purposes, including annotation (Hildebrand et al., 2013), transcription, contextualisation, classification (Oomen and Aroyo, 2011) and bringing art & culture to a general audience (Bellotti et al., 2012). Crowdsourcing and gamification are techniques used to achieve audience engagement with the cultural heritage. As audience engagement is a key success factor for UGESCO's metadata validation and collection, it was a crucial element to investigate. Numerous authors point out challenges related to this engagement. Hildebrand et al. (2013), for example, point out the necessity of an active user community – a community that can be built through engaging the audience. Oomen et al. identify two main types of motivation: motivation through feelings of connectedness and membership, and motivation through sharing and generosity. Besides these two types, they identify altruism, fun and competition – the latter two being of particular interest in gamification strategies.

SOTA / OBJECTIVES in spatio-temporal querying/exploration/mapping of collection data

A good example of a technologically similar application is the swisstopo geo-admin map viewer (http://map.geo.admin.ch), which offers a time slider to change the currently viewed time period and a side-by-side comparison tool to compare the situation at specific dates. The swisstopo viewer is free and open source (source available at https://github.com/geoadmin/mf-geoadmin3) and based on cutting edge, yet widely supported web technologies such as OpenLayers 3, AngularJS and Twitter Bootstrap, which makes it very adaptable and a good technical starting point for our application.

3. METHODOLOGY

Detection of spatio-temporal named entities

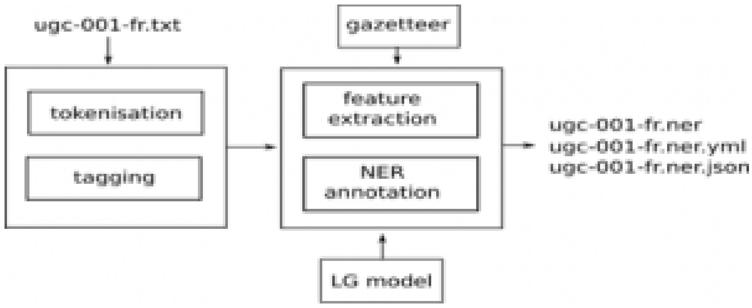
Natural language processing (NLP) tools are used to detect words and phrases expressing location and time. The NLP task used to detect these spatio-temporal expressions is called “named entity recognition” (NER). UGESCO’s NER task differs in various aspects from previous NER projects, involving a number of challenges related to the nature and the type of texts used for picture descriptions and the types of enrichments required for geo-temporal named entity recognition.

Originally, NER was limited to the detection of proper nouns referring to names of persons, organizations and locations, but the categories were later on extended to other types, including numerical information (referring to time, date and different numbering systems). In UGESCO, we limit NER to two main categories: location and time. The location category is expanded from the general LOC type (referring to any type of location, including names of cities, regions or countries) to a set of subcategories, including POIs. The following LOC subcategories are used: PLACE, STREET, ROAD, WATERWAY, BUILDING, SPACE and MONUMENT. In the case of timestamps, the TIMEX categories are used. This subcategorization facilitates fine-grained selection of locations and time.

The main issue of NER processing in the UGESCO project is the brevity and the structure of the photo descriptions. Unlike ordinary running text, text samples describing pictures are usually short texts, lacking co-textual information, necessary to disambiguate the words. Moreover, description fields often have a reduced syntactic structure (e.g. subject missing, use of infinitives), so that specific training and/or adaptation of existing NLP tools is required.

The figure below gives a schematic overview of the different steps used in the NER processing. As an example, we use a French input text (ugc-001-fr.txt), but the same approach is used for texts in any other language. First of all, some pre-processing is required: the text is cleaned, tokenized and tagged. Tokenization involves the process of separating words from non-words (e.g. punctuation). Each token is then assigned a part-of-speech tag, indicating the word category, so that you can distinguish verbs from nouns or any other word category. After pre-processing the tokens, the NER process can start, using two extra inputs: the language model (LG) and a gazetteer. The LG model is the result of a supervised training process, based on previously annotated data and template based algorithm for NER detection. The gazetteer is principally a kind of location dictionary, containing a set of commonly used locations. On the basis of these extra resources, the NER process detects named entities in the text samples.

The result of the NER process is stored in an output file (ugc-001-fr.ner), and in two extra files in a special format (output ending in yml and json), which enables further processing by other tools.



NER PROCESSING OF PICTURE LABELS

Computer vision-based place recognition

In case NER is not able to detect the exact location of a particular image (or in case we want to validate the NER output) we can detect the location (or some of its features) by using one of the computer vision based geolocalization algorithms that have been proposed in literature. Feature matching with georeferenced image datasets is by far the most useful/accurate geolocalization technique. Based on a feature point matching algorithm, this algorithm searches the best match of the POI image within a dataset of georeferenced images that are taken in the POI neighborhood. However, such georeferenced dataset will not always be available or it will be computationally too hard to build it up. For this reason, we introduce a place recognition filtering step based on semantic scene understanding. The generated semantic features facilitate the construction of a georeferenced dataset. The approach that is most closely related to our setup is the hierarchical, multi-modal approach of Kelm et al. for georeferencing Flickr videos. Both textual toponym identification in video metadata and visual features of the video key frames are used to identify similar content. Their approach, however, is still global and the accuracy is rather limited, i.e., only one third of the video dataset is correctly geotagged within a 1 km error margin, which is too limited for UGESCO's desired search relevance and querying efficiency and effectivity.

Semantic scene understanding for place recognition. Visual scene recognition is a trending topic since last few years. Previous studies heavily focused on feature engineering where features are generated based on statistical analysis, previous knowledge and feature performance evaluation. This requires expensive human labour and mostly relies on expert knowledge. A more recent trend is to use feature learning techniques where different positive and negative samples are shown to the system and, based on these examples, the parameters of the network are changed accordingly. Feature learning mechanisms achieve outstanding results compared to handcrafted features for different localization tasks, which is also the reason for using it in UGESCO. A trained convolutional neural network (CNN) such as Places365-VGG is able to give scene predictions and their corresponding prediction confidence. In combination with a semantic vocabulary and appropriate semantic distance measures, this allows us to fine-tune and determine the context of the scene.

UGESCO's place recognition tool tags each image with a set of semantic descriptors using the MIT places model and Dense captioning techniques. The Places model suggest the most likely place categories representing the image, using Places-CNN, and identifies if the image is an indoor or an outdoor place. The indoor/outdoor information is also used to select the correct mode (indoor/outdoor) in the Street View mapping and rephotography. The output of the places model can also be used for data filtering and picture grouping. In the CegeSoma collection, for example, we can easily filter out pictures that do not contain location clues or we can group pictures based on semantic concepts (such as building types like churches and castles). In order to improve the image categorization, we will also analyze the co-occurrence of semantic concepts. The figure below shows the output of the place recognition on some pictures of the CegeSoma collection. This output can be further optimized by also taking into account semantic relationships between the suggested keywords.

PLACE RECOGNITION RESULTS – PICTURES FROM CEGESOMA COLLECTION.

*Street view scraping and matching***.** Depending on the metadata output of the NER and computer vision modules, different strategies for Street View matching have been developed to find the exact location of an image if we only have its city or street name. If, for example, NER tells us the street and city name, we can request/extract an Open Street Map (OSM) street polygon, process the Street View (SV) panorama images of this region (to create a SV dataset), filter the SV dataset on semantic similarity (based on places output – or other CNNs) and match the query image to the SV dataset (as shown in the figure below).

Of course, NER and computer vision output will not always be able to give such detailed location estimation. If, for example, we only know that it is a church in Ghent, we will first query DBpedia for all churches in Ghent and use address geocoding to build up the SV datasets of all possible candidates. If we don't know the city, or we can't find a good match, we will try to get more detailed information from the named entity disambiguation step or collect crowdsourced contributions of the particular image.

STREETVIEW SCRAPING – MATCHING WITH GEOREFERENCED DATASET

Named entity disambiguation

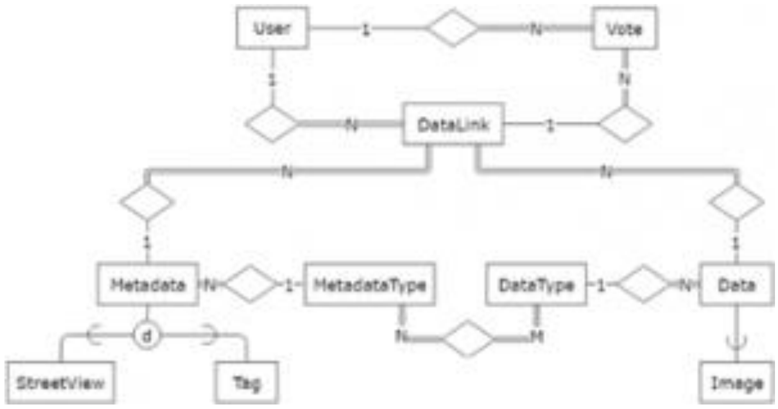
The NER and computer vision phase result in a list of names of locations mentioned in the photo captions or found by the visual place recognition algorithm. However, as already discussed, this information will frequently be too vague to perform a good location estimation or will lead to conflicting NER and computer vision results. For example: “Gare du Nord” does not tell us much if we don’t have additional location info. Which “Gare du Nord” is it? Is it in Brussels or Paris? And what does “Cinquantenaire” mean, which has several pages in Wikipedia? To find the answer, we need to be able to link each of these locations to a standardized entry in a database, then choose the one that is most likely the place where the picture was taken. This process of trying to automatically link words in a document (e.g. place names) to an external database (e.g. Wikipedia) is called “Entity Linking”, “Named Entity Disambiguation”, “Reconciliation” or “Entity resolution”. Although much progress has been made since the seminal works, the task is far from being solved. Its difficulty varies according to the quality and the length of the text. A tweet or a SMS, for example, can be ambiguous even for a human. The same goes for short photo captions. The temporal context is also important. When a picture taken in 1940s says that the scene took place in “Hamme, Belgium”, we must not forget that, at the time, at least three Belgian municipalities had this name.

The proposed method of disambiguation uses original clues from the photo database, i.e., the thesaurus keywords that archivists have applied to folders containing groups of photos related to the same theme. These keywords sometimes contain a place name, such as a city, a province, or a region. Using these terms, which we parsed out from the keywords, we will apply an algorithm that will query Wikidata[1] using SPARQL[2] queries and API calls. For each location previously extracted from the photo captions and the computer vision output, the algorithm will select the possible candidates and choose the most likely based on the available clues.

When multiple places are mentioned in the same picture, it will use the same clues to rule out the least likely. The results of the computer vision are also used to perform the disambiguation. In the case of “Cinquantenaire”, which can refer to both a park, a museum or a bridge, the classes mentioned by the computer vision (e.g. “Bridge”) will help to determine the most appropriate entry. When computer vision predictions seem to contradict each other (for example if the place can be a church, a synagogue or a palace at the same time), Wikidata’s ontology is used to find the broader category that “subsume” these classes (in this case, the superclass “Building”). Finally, if the ambiguity is too strong, the system will not try to guess further and will simply indicate that this text or this photo must be verified by the crowd. The first results obtained from a sample of pictures are encouraging and must now be tested on a larger scale and later subjected to a human evaluation.

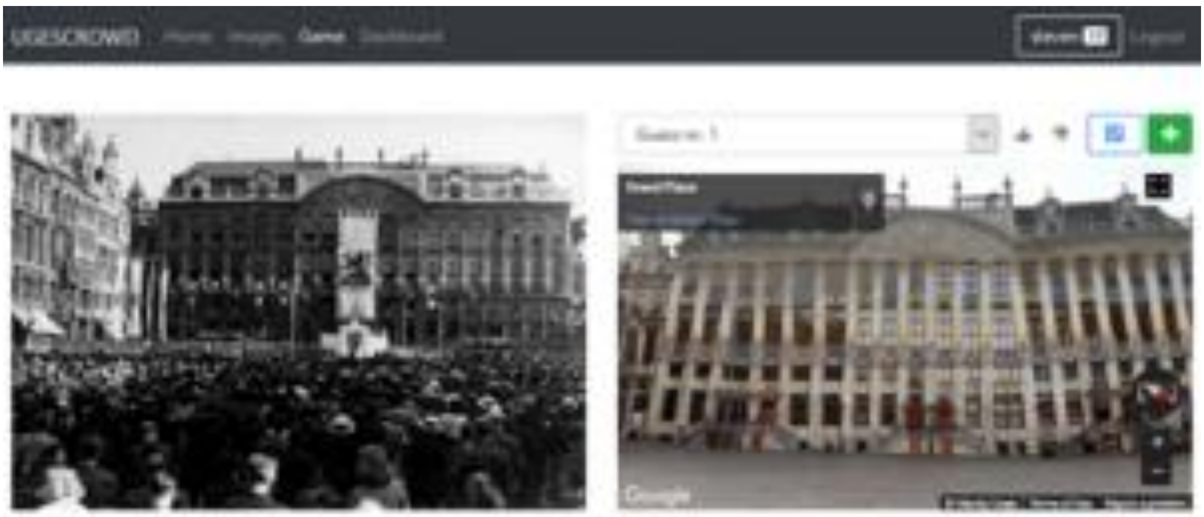
Crowdsourced validation and enrichment

To further improve the outcome of the automatic enrichment tools we created a generic dashboard for crowdsourced enrichment of multimedia collections. The general architecture of the Django[1]-based dashboard is shown in the figure below. This set-up allows users to vote for different types of datalinks and to add new datalinks. Each datalink consists of a data object (such as an image) and a metadata object (e.g., its location, time period, keyword). The votes and the quality of the datalinks of each user are used to generate a credibility score. Based on this score, his/her contributions will have more (or less) impact on the UGESCO metadata generation.



GENERAL ARCHITECTURE OF THE UGESCO GENERIC DASHBOARD FOR CROWDSOURCED ENRICHMENT OF MULTIMEDIA COLLECTIONS.

The user interface of the dashboard is shown below and can be evaluated at the UGESCO website. Crowdsourced rephotography is not yet fully supported, but will be integrated soon – a PhD has been started on this topic at Ghent University.



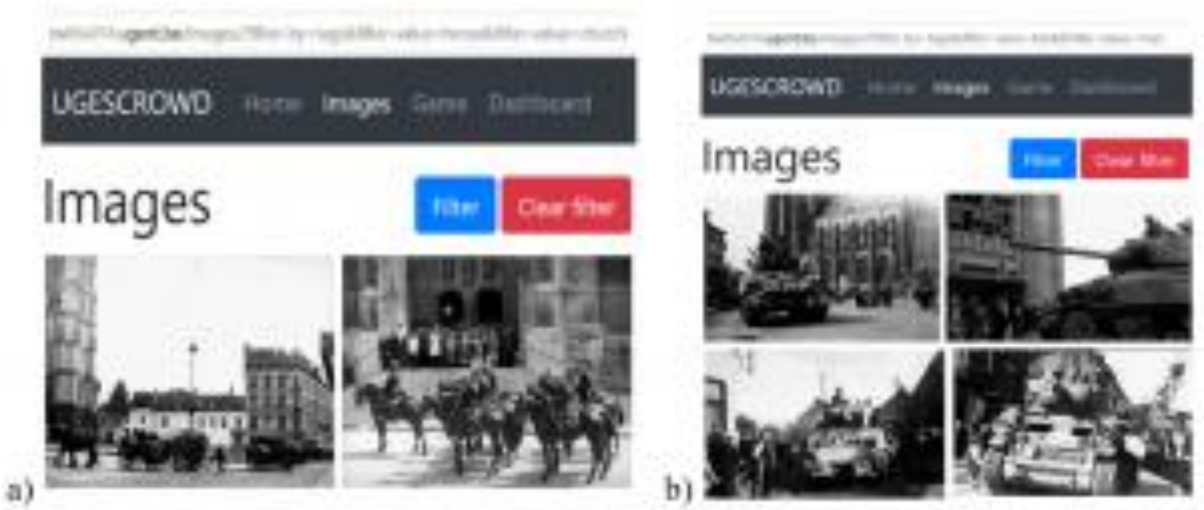
UGESCO DASHBOARD FOR CROWDSOURCED ENRICHMENT – STREET VIEW LOCALIZATION TASK.

Crowdsourced rephotography – Aligning a historical photograph in a modern rephotograph (or vice versa) can serve as a remarkable visualization of the passage of time and can be used across a plethora of application domains (e.g., tourism, media and interactive museum applications). Crowdsourced and computational rephotography modules try to accurately map images of the past on the buildings and landscapes of today. Estimation of FOV can be found automatically by following a random sample consensus (RANSAC) homography matching. Another approach, focusing on outlier filtering and viewpoint clustering, is proposed by Makantasis et al.. However, in order to optimize and validate the results of these approaches, a crowdsourced rephotography module will be integrated in the dashboard. The figure below shows an example of how this is currently done. It is important to mention, however, that the geometric alignment is still rather basic and requires more research/development. However, the tool already allows to zoom, navigate around and change transparency of the collection picture, which continuously is dynamically placed at its correct Street View location. These crowdsourced dynamic image overlays can be used to improve the computational algorithms, i.e., they can learn from the crowd's actions.

REPHOTOGRAPHY TOOL TO ALIGN A HISTORICAL PHOTOGRAPH WITH ITS STREET VIEW LOCATION.

Metadata filtering and clustering

The first web-based tool that can be used to explore the enriched collections is a metadata filtering & clustering service. Several metadata types and values can be defined as filter. The figure below, for example, shows the result of querying the collection for images that (a) contain a horse and a church, or (b) a tank and a man. These and other types of queries can be evaluated at the UGESCO website. Furthermore, we are also investigating a methodology to cluster the pictures based on their semantic similarity. In this context, the Object Relation Network and bag of semantics seems interesting mechanisms. However, other approaches will also be evaluated.

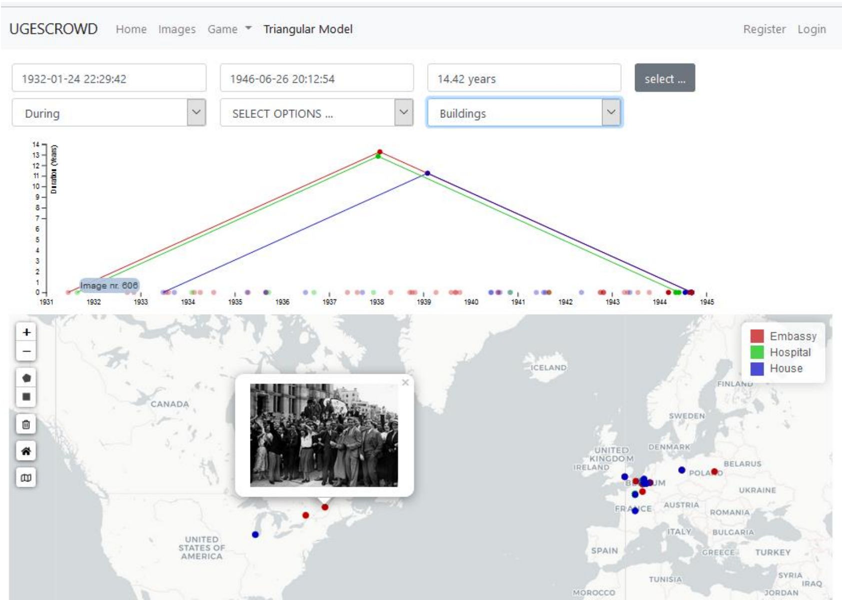


METADATA FILTERING AND CLUSTERING SERVICE

WebGIS for spatio-temporal data exploration

The UGESCO WebGIS lets end users explore the enriched datasets using temporal and spatial mapping tools, and study how the data evolves in time and space. The time intervals are structured within the interactive Triangular Model (TM), where each point is a time interval with the center of the interval on the x-axis and the duration on the y-axis. The WebGIS allows user to select specific objects based on different Allen relations and derivatives, and to combine them with the basis of set theory on the TM or the map. An example of the TM is shown in the figure below.

The WebGIS is implemented in Javascript and uses i) the Leaflet library for generating the interactive maps, ii) plotly.js as graphing library for the TM and iii) turf.js for the advanced geospatial analysis.



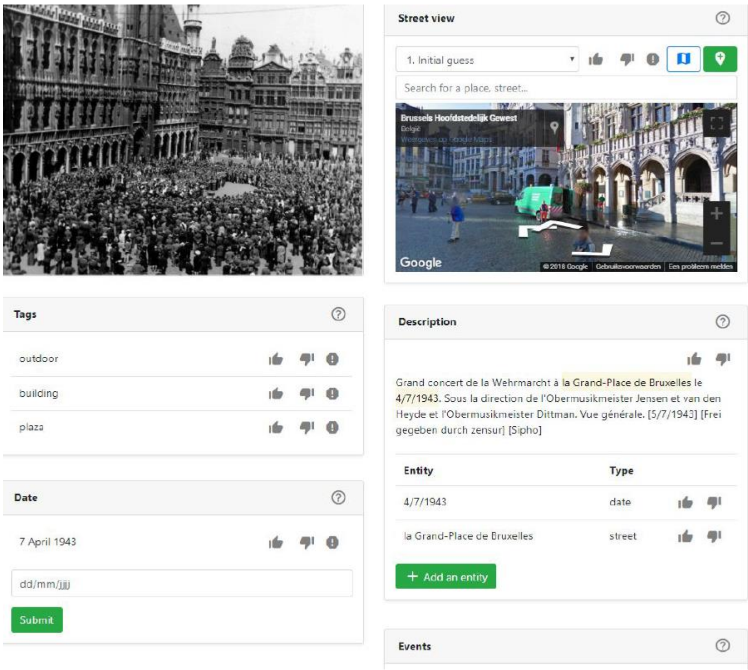
4. SCIENTIFIC RESULTS AND RECOMMENDATIONS

The current status of the UGESCO building blocks allow us to perform spatio-temporal enrichments on the CEGESOMA datasets. Further optimizations will be needed to further improve the accuracy of the NER, computer vision and disambiguation algorithms. Crowdsourced micro-tasks, which can be performed on the UGESCROWD platform, help in validating our enrichments and the collection of missing data. This input, on its turn, is used to further optimize the NER/computer vision.

The following technological building blocks of the UGESCO framework can be tested on our website/ugescrowd platform:

- place/object recognition
- webGIS for spatio-temporal data exploration
- filtering/clustering
- named entity recognition
- visual/textual similarity search

In order to evaluate the (re)usability of our technologies/platform, we also investigated the feasibility for other/new collections during the last year of the project. Multimedia data of the academic heritage archives of UGENT, for example, are used to evaluate the cross-collection performance and to develop/test tools which cannot directly be evaluated on the CegeSoma collections (such as the HTR building block).



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We combined each of the developed building blocks into one single service for the FSI, which generates enriched (meta)data for their collection items in a standardized format (json) that they can import in their existing infrastructures.

The image recognition pipeline will be further optimized by IDLab in other CH projects – several of the generic tools that are used in our hierarchical approach will be adapted to perform better on the specific heritage content features.

5. DISSEMINATION AND VALORISATION

01/04/2017 UGESCO kickoff @ Ghent University.
Contributions : input/feedback on project goals/planning

11/09/2017 UGESCO presentation at Digital Dreams @ De Krook, Ghent.
Contributions : feedback on envisioned architecture/enrichment pipeline

12/09/2017 1st Year of the Project / Intermediate Results Presentation
Contributions: evaluation of the current status of each of the building blocks and brainstorm/suggestions for improvement

11/09/2017 UGESCO presentation at Digital Dreams @ De Krook, Ghent
https://socialhistory.org/en/events/ialhi-conference-2017-digital-dreams

08/10/2017 UGESCROWD demo @ 200Y UGent festival

05/12/2017 presentation/demo @ Media Fast Forward (VRT)

29/10/2018 EUROMED conference presentation (https://euromed2018.eu/)

11-15/11/2018 VISUAL HERITAGE conference panel discussion (http://2018.visualheritage.org/)

24/04/2019 CHANGE workshop – presentation of Image Recognition Pipeline

06/05/2019 Demo - International workshop/seminar at TU Wien, Austria (M. Sc. Cartography)

12/09/2019 Closing event UGESCO/EURECA @ CINEMATEC

21/10/2019 Digitale Week – Liberas – general project overview presentation

Several one-on-one meetings / mail communications have also took place over the last years between UGESCO partners and the members of the follow-up committee (e.g. meetings between CegeSoma and KIK-IRPA/CINEMATEK, meetings between IDLab and Universiteitsarchief & ARhus). The outcome/results of these meetings were discussed at one of the 8 bi-monthly technical meetings of the UGESCO team.

With some members of the follow-up committee new project proposals (related to UGESCO) were also submitted (e.g. an international network proposal with CINEMATEK, a collaboration with Universiteitsarchief UGent and VIAA in the recently started Flore de Gand project, etc.).

6. PUBLICATIONS

Steven Verstockt, Samnang Nop, Florian Vandecasteele, Tim Baert, Nico Van de Weghe, Hans Paulussen, Ettore Rizza, and Mathieu Roeges, UGESCO – A hybrid platform for geo-temporal enrichment of digital photo collections based on computational and crowdsourced metadata generation – EUROMED 2018 international conference on digital heritage.

https://link.springer.com/chapter/10.1007/978-3-030-01762-0_10

Paulussen Hans, Rizz, Ettore, Van Hooland Seth & Dirk De Hertog (2018). "Détection D'entités Nommées Spatiales Et Temporelles Dans Les Légendes D'archives Photographiques." Actes De L'atelier EXCES - EXtraction de Connaissances à partir de donnéEs Spatialisées (2018): 13-21.

https://difusion.ulb.ac.be/vufind/Record/ULB-DIPOT:oai:dipot.ulb.ac.be:2013/280050/TOC

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- Bruno De Wever - Co-director of the Institute of Public History and WWII expert, History Department, Ghent University
- Matthias Priem - VIAA
- Bruno Daems - ARhus – Roeselare Knowledge Centre
- Heidi Vandenbosch - IWT SBO Friendly ATTAC
- Tijs De Schacht - Ergoedcel Erfgoed ZuidWest
- Davy Hanegreefs - Royal Belgian Film Archive (Cinematek) / CHANGE network coordinator
- Samuel Donvil - Packed (Expertisecentrum Digitaal Erfgoed)

ANNEXES