GeoComBi - Geospatial context enriched image annotation in BIIGLE 2.0

Tim W. Nattkemper[1]
[1] AG Biodata Mining, Faculty of Technology, Bielefeld University
Date of submission: March 29th, 2023

Abstract
Image and video data interpretation and annotation has become a bottleneck problem in many fields of earth sciences due to the advances in imaging techniques, camera platforms and the ongoing increase of volume recorded. Online image and video annotation tools such as BIIGLE 2.0 (> 2,100 users, March 2023) made the organization, sharing, inspection and semantic annotation of imagedata more efficient - for human interpretation and for the generation of training data for AI systems. A current limitation of the inspection process represents the lack of geospatial context as users interpret the visual data only using the pixel information, neglecting the geospatial dimension and background. In this pilot, we will implement two new BIIGLE 2.0 functions to provide geospatial context information in the images/video annotation. First, a new geospatial browsing visualization will be implemented to display the positions of images/video frames and the related annotations. Second, a new geospatial context fusion function will combine a single image with visual spatial context information (e.g. a mosaic) so users can gain and use a mental model of the surrounding area. The two functions will be available for all BIIGLE 2.0 users, and like the BIIGLE 2.0 source code, publicly available under GPL 3.0 license. The BIIGLE 2.0 user community ranges from Biology/Biodiversity research over Environmental Sciences to Earth Sciences. Extending BIIGLE 2.0 with the functions we propose here will make the interpretation and analysis of the visual data more efficient and allows users to integrate more geospatial information in the image interpretation. This will lead to a more intense use of BIIGLE 2.0 by a larger community which could have a positive effect on streamlining image analysis and the definition of best practices in image analysis workflows.

I. Introduction: In the last 20 years, digital imaging and video (in the remainder we will use the term “visual data” that relates to digital images and video) has evolved due to several technical advances. Nowadays, large areas and habitats are inspected with remotely controlled vehicles (e.g. ROV (remotely operated vehicle) or UAV (Unmanned Aerial Vehicle)), autonomous vehicles (e.g. AUV (Autonomous Underwater Vehicle)) or fixed observatory platforms and terabytes of visual data can be collected in a single exploration or monitoring campaign. The analysis of the visual data includes different kinds of semantic interpretation and annotation steps like assigning the whole image or a region of interest to a semantic category, which could be a habitat category, an event category, a species description/morphotype/taxonomy or something else. This process is time-consuming and requires domain experience. As the recorded data keeps growing in volume and resolution and the number of expert time for interpretation is limited, a serious bottleneck situation has arisen. To make the visual data analysis more efficient and effective, online image/video annotation tools have been proposed that allow users to share data, annotate data with standardized catalogs, visualize results and export the results as spreadsheets for subsequent statistical analysis. Among the most prominent tools that represent the state of the art in this area are VIAME, CoralNet and BIIGLE 2.0 (www.biigle.de) [Langenkämper et al. 2017, Zurowietz et al. 2021], which has been developed by the Biodata Mining Group at Bielefeld University in Germany (see Figure 1). However, although the visual inspection and semantic annotation

Figure 1: The online image and video annotation tool BIIGLE 2.0 supports image / video analysis tasks, like detecting / marking objects, taxonomic assignment / object classification (upper center and left), development / standardization of catalogs (upper right) and quality assessment / inspection (lower center). Examples show deep sea benthos, and aerial images from the Galapagos (copyright Dr. Amy MacLeod, "Iguanas from above" project). Numbers in the lower right are from March 2023.

is now supported by such tools and some of them even offer machine learning modules to automate some steps in the annotation, the tools do not support an integrative analysis of geospatial information and visual data.
In the proposed pilot project we want to develop new BIIGLE 2.0 functions that allow users to include geospatial context information in the interpretation of visual data. Linking the image interpretation step to information about the large scale profile of the landscape / sea floor has the potential to accelerate the analysis by geospatial filtering, to support an early interpretation of the geospatial layout of annotated species or to support the decision in object classification by integrating morphological visual features and geospatial features displayed. In summary, an integrative multimodal (visual + geospatial data) approach should have several positive effects on the depth and significance in visual data interpretation by enriching geospatial information with information derived from visual data.

II. Pilot description: BIIGLE 2.0 is a web application written in the PHP and JavaScript languages with the Laravel and Vue.js application frameworks. A deployment of the software is based on an Nginx webserver, PHP-FPM application server and PostgreSQL database as Docker containers managed by Docker Compose. In this pilot, we will implement the two following new functions to make use of geospatial information in BIIGLE 2.0. Prerequisite is that GPS coordinates are available for the visual data and the geospatial map is available as a georeferenced two-dimensional grid (e.g. a backscatter map, a bathymetry or a photo mosaic) through a web map service (e.g. WMS). The two new functions will be implemented following BIIGLE's general modular design.
Geospatial browsing and filtering: Image collections from one dive (transect) or one UAV flight are organized in so called volumes in BIIGLE. The proposed pilot project will support the users to link one volume to one (or more) maps. Geospatial coordinates of images are usually present in the file headers of the images or via metadata files such as iFDOs (image FAIR (Findable, Accessible, Interoperable, Re-usable)) Digital Objects [Schoening et al

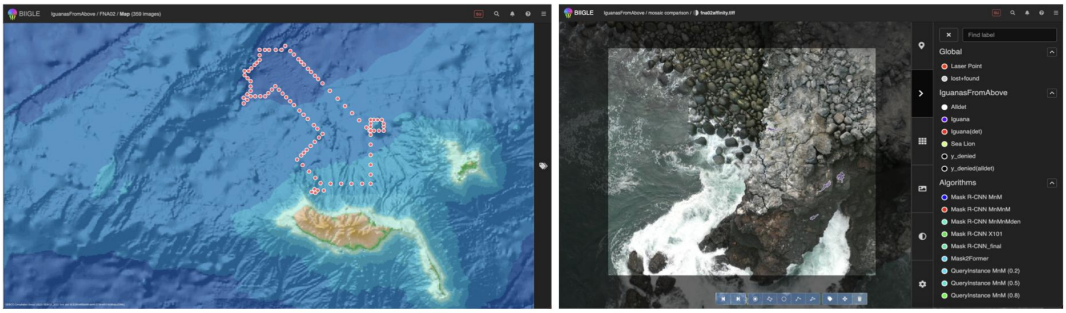

Figure 2: Illustrations for the two geospatial visualization features developed in this pilot project. ***Left****: Positions of images (i.e. the vehicle carrying the camera) are displayed on a bathymetric map so users can filter images condition to geospatial features or display subsets of images.* ***Right:*** *A single image from a drone flight image set is shown with a mosaic of all images in the background. The surrounding visual information guides users assessing to obtain geospatial context information.*

2022]). Using BIIGLE's filter tab allows users to display the map together for instance with the positions of images in the volume (see Fig. 2 left). This map display can be used to display all images available so that users can select a subset condition for geospatial features or to select a subset of images after the annotation (for instance all images showing a particular species) and visualize the positions of these images in the map. We will investigate the potential of collaborating with other pilots such as "Bathy4All: Workflows for Multibeam Processing and Visualization" or "German Marine Seismic Data Access".
Geospatial context fusion display: A visualization function will be implemented to display georeferenced grids as context information in the image annotation tool of BIIGLE. To this end, we will develop a protocol for linking images provided with geospatial coordinates in a volume to a web-accessible map, for instance a georeferenced photo-mosaic. In the image annotation tool, the linked georeferenced grid(s) will then be displayed as surrounding "background" information around the computed position of the current image and/or annotations (cmp. Fig. 2).

III. Relevance for the NFDI4Earth: BIIGLE acts as a key element of the data value chain, particularly through harvesting human expert knowledge for earth system research as well as for the tuning of AI systems. It addresses different steps of the research data life cycle, like *Data Analysis* (like manual/automatic annotation), *Preserving Data* (sustainable management of taxonomic catalogs) or *Giving Access to Data* (sharing data and collaboration in BIIGLE projects). An existing, yet under-exploited aspect of BIIGLE lies in data reuse, which will become more relevant through the proposed activities. By providing spatial context, data re-use capacity becomes easier to assess and as such BIIGLE will become operational to further support the data acquisition planning step of the data life cycle. BIIGLE already is the pioneering software tool to implement the image FAIR Digital Object concept (iFDOs, see above) for marine, terrestrial and planetary imagery. Other elements of the FAIR image infrastructure are provided through collaboration partners such as GEOMAR (e.g. handle server to enable persistent identification of georeferenced grids, image data sets and potentially label catalogs as well as an OAI-PMH catalog service to publish the availability of image data set and maps for data re-use). As such, this project will bring several data management and infrastructure concepts and demonstrator functionality into operationality for earth system scientists.

Besides the group of researchers, public administration and spatial planners and other decision makers may also benefit from BIIGLE 2.0 in case large image collections need to be integrated in GIS workflows. Through building on standardized interfaces (e.g. iFDOs, OAI-PMH, WMS) the proposed activities also supplement the further modularization of the FAIR marine image management and analysis lifecycle. Hence, they are important contributors towards efficient cross-domain data fusion (e.g. acoustic grids with optical images), e.g. for knowledge transfer solutions such as Digital Twin applications.

IV. Deliverables: The two new BIIGLE functions will be made available for all users of biigle.de as well as institutes running their own BIIGLE instances and the code will be made available as ~~open~~ source.

V. Work Plan & Requested funding: The work will be carried out by Mr. Max Tiessen according to the plan below, a programmer experienced in BIIGLE development. Ms. Leane Hecht is a backup candidate for this position.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Geospatial browsing and filtering												
Geospatial context fusion display												

Requested funds	12 months TVL ÖD E13 for one scientific programmer: EUR 71.163,36 €
in-kind contributions	4 months student assistant 9h/week: 4.704,69 € (in-kind contribution Uni Bielefeld) 400 € travel costs (in-kind contribution Uni Bielefeld)

VI. Supplementary note on the role of the applicant: Bielefeld University is currently not an active member of the NFDI4Earth consortium. Membership would allow us to further improve the BIIGLE tool together with the Earth Sciences community and would like to actively participate in “Education & Training”, e.g. organizing an image annotation EduHub or by contributing BIIGLE training courses for the Academy program. Such courses could also be combined with education activities regarding machine learning. The team could also contribute in NFDI4Earth interest groups about FAIR data or machine learning, which requires many annotated data i.e. images. GEOMAR is a member of the NFDI4Earth and sees the activities of the proposed project as contributions to its diverse data management and data science efforts (e.g. the Helmholtz Metadata collaboration to make marine image data FAIR, the Helmholtz DataHub activities to federate FAIR image data across research centers and the marine-data.de portal).

Literature:

[Langenkämper et al. 2017] BIIGLE 2.0 - Browsing and Annotating Large Marine Image Collections. Langenkämper D, Zurowietz M, Schoening T, Nattkemper TW. Frontiers in Marine Science, 4, 2017, 83, DOI=10.3389/fmars.2017.00083, ISSN=2296-7745

[Schoening et al. 2022] Making marine image data FAIR. T Schoening, J Durden, C Faber, J Felden, K Heger, HJ Hoving, R Kiko, K Köser, KO Möller, D Nakath, A Naß, TW Nattkemper, A Purser, and M Zurowietz. SCIENTIFIC DATA, 9, 414 (2022). https://doi.org/10.1038/s41597-022-01491-3

[Zurowietz et al. 2021] Current trends and future directions of large scale image and video annotation: Observations from four years of BIIGLE 2.0. M Zurowietz, TW Nattkemper, FRONTIERS IN MARINE SCIENCE (section Ocean Observation), 2021, Manuscript ID: 760036A