SOP: iFDO Creation

The **purpose** of this Standard Operating Procedure (SOP) is to document the necessary steps to **create FAIR Digital Objects for images** (iFDOs) containing standardized metadata for marine research images (photos and videos).

The **goal** of this document is to **enable all stakeholders** to create iFDO files according to their research needs and use cases and to provide hints as to how the iFDO creation can be conducted by open source software.

The **scope** of this SOP includes the steps from collecting general project information on the image acquisition, the documentation of acquisition steps and the image and metadata curation steps. Included in the iFDOs can be information on the purpose of imaging, on the semantics of objects in the images, on image capture specifics and much more. This SOP provides context and guidance for all of those.

Completing the SOP will **result** in metadata for image data sets that adheres to the international iFDO standard, that enables efficient analysis and browsing of large image data sets in tools like QGIS and BIIGLE.

Introduction

Achieving FAIRness and Openness of (marine) image data requires structured and standardised metadata on the image data itself and the visual and semantic image data content. This metadata shall be provided in the form of FAIR digital objects (FDOs).

iFDOs consist of various metadata fields. Some are required, some are recommended, some are optional. You will only achieve FAIRness of your image data with the required iFDO *core* fields populated. You will only gain visibility and credit for your image data with the recommended iFDO *capture* fields populated. And you will only have awesome image data in case you also populate the iFDO *content* fields. As a bonus you can add your own domain-specific optional fields. The iFDOs standard aspires to be the most complete standard that allows to bridge between existing standards (like DublinCore, Audubon, SmartarID, PDS4) while filling gaps of those.

All image metadata shall be stored in one image FAIR digital object (iFDO) file. This file shall contain all iFDO metadata fields. It does not contain the actual image data, only references to it through persistent identifiers! The file should be human and machine-readable, hence *.yaml format is recommended. The file name should be unique, we recommend: <image-project>_<image-event>_<image-sensor>_iFDO.yaml.

An iFDO file consists of two parts: the image-set-header part and the image-set-items part. The header part contains default values for all items. The items part contains all values that deviate from the default values for this specific image item. All metadata of an image-item is provided in a list. For still images (aka photos) this list has only one object as an entry. For videos, the first entry of the list contains an object of those metadata fields that are defaults for the entire video. All subsequent list entries correspond to specifications of the metadata for one given timepoint of the video.

The iFDO standard defines three different section that cover different aspects of FAIRness and target increasing usability of the image metadata. The iFDO core section contains the required metadata that makes image data sets FAIR. The iFDO capture section contains metadata fields that describe how the image data was created. The iFDO content section describes what is going on in the image data in terms of information or annotations.

Preparation phase (required)

1. Scientists provide input data for iFDO creation

Result: *Curated image and navigation data and general project information.*

Info: To create iFDOs input data is required. This includes a) general project information like the ORCID of the PI; b) curated image data with well-formed file names and UUIDs in the metadata; c) quality-controlled navigation data; d) a protocol on the image acquisition.

Tip: See "SOP Image curation" for details (steps 1 – 6 therein).

iFDO core (required)

2. Scientists provide the context of the image acquisition. → FAIR

Result: *Information for the fields* `image-context`, `image-project`, `image-event`, `image-set-name`, `image-abstract`.

Info: This information allows to group images into categories and to link user access and usage policies to the image data sets. These five metadata fields are likely static for an image set and thus occur almost always in the `image-set-header` part.

`image-context`	String	The broader context of the image acquisition. Could be a large proposal. Could be a (inter)national research mission. Could be a grand challenge. Probably a short string.
`image-project`	String	The direct context of image acquisition. Could be a cruise. Could be a field campaign. Could be a field season. Probably a short acronym.
`image-event`	String	One specific event of a project or expedition or cruise or experiment or … This is most often a single camera deployment (an ROV dive, a drone flight, etc.). Probably a unique identifier like a DSHIP event.
`image-set-name`	String	A slightly longer string that is a unique name for the image set. Should include `<image-project>`, `<image-event>`, `<image-sensor>` and may include information on the "purpose" or on the "location" of the image acquisition. This is probably how you would refer to the image data set in conversation.
`image-abstract`	Text	A short text of 500 - 2000 characters describing what, when, where, why and how the data was collected. Includes information on the `<image-event>`, e.g. overlap between images/frames, parameters on platform movement, aims, purpose of image capture etc.

Tip: Re-use information from a project description file or project curation Git for these fields.

3. Scientists provide data usage and data responsibility information. → FAIR

Result: *Information for the fields* `image-pi`, `image-creators`, `image-license`, `image-copyright`.

Info: This information allows users of the data to assess which usage rights are assigned to the image data (i.e. how they may re-use it) and who is responsible for the creation of the data from the project side and the technical side.

`image-pi`	Dictionary	The one principal investigator who is responsible for the creation of this image set. Could be a (sub)project coordinator. Could be a

		cruise PI. Could be a field campaign lead. This dictionary should include an ORCID, name and email address: `image-pi: {orcid:XXX, name:Peter Perker}`
`image-creators`	List	A list of at least one person that are responsible for the creation of the image data from a technical standpoint. Could be a PhD student. Could be a technician. Could be a robotics team. Should include the same information as for the `image-pi`: `image-creators: [{orcid:XXX, name:Stan Loo},…]`
`image-license`	String	An identifier to specify the license to use the image data. This license should be FAIR, otherwise the whole iFDO excersise is useless! Could be “CC-BY” or “CC-0”.
`image-copyright`	Text	A copyright statement of who the data belongs to. Of whom to contact in case of data licensing or usage request.

Tip: Re-use information from a project description file or project curation Git for these fields.

4. Scientists provide technical information on the gear used for image creation. → FAIR

Result: *Information for the fields* `image-platform`, `image-sensor`.

Info: This information allows connect the image data to specific imaging hardware. It is essential to use persistent identifiers for the camera platforms and camera sensors.

`image-platform`	String	A unique identifier of the platforms used for image acquisition. Do not only use “OFOS” or “ROV”. Identify the specific gear: e.g. “ROV-KIEL6000” or “AWI-OFOBS”. Should be a recognizable identifier to a proven gear database like AWI Sensors or GEOMAR Equipment Git or the MFP.
`image-sensor`	String	A unique identifier of the sensors used for imaging. This is most likely a camera. Do not only use “GoPro” or “LOKI”. Identify the specific gear: e.g. “GoPro_Hero6_123456” (where 123456 is the serial number of the manufacturer of this specific device). This should be a recognizable identifier to a proven gear database like AWI Sensors or GEOMAR Equipment Git or the MFP.

Tip: Re-use information from a project description file or project curation Git for these fields.

5. Scientists provide navigation data. → FAIR

Result: *Information for the fields* `image-datetime`, `image-longitude`, `image-latitude`, `image-depth`, `image-altitude`, `image-coordinate-reference-system`, `image-coordinate-uncertainty-meters`.

Info: This information allows to geo-reference image data within a reference region. 4D navigation data is needed on the time of acquisition and the 3D spatial coordinate. The time information has to be in UTC. The x,y location (`image-latitude` and `image-longitude`) needs to be given together with the respective coordinate-reference-system (`image-coordinate-reference-system`). The `image-coordinate-uncertainty` value needs to be given to assess the quality of image geo-referencing which influences the re-usability of image data. Navigation data is most often required per photo or per second of video. Usually this information is incorporated into the `image-set-items` part as per-image information. The `image-coordinate-reference-system` and `image-coordinate-uncertainty-meters` information is usually incorporated into the `image-set-header` part once as a static value.

`image-datetime`	String	The validated UTC time of image acquisition. We recommend one value per second. The format should be YYYY-MM-DD HH:MM:SS.SSSSS. Should a different format be used then a field `image-datetime-format` is required for parsing.
`image-longitude`	Float	The curated y position of image acquisition. Should be a decimal degree value between -180° and 180°. You may put UTM values in here if you have to.
`image-latitude`	Float	The curated x position of image acquisition. Should be a decimal degree value between -90° and 90°. You may put UTM values in here if you have to.

`image-depth`	Float	The curated z position of image acquisition. Use this field when the camera is *below the sea surface* (else use `image-altitude`). Then the values are positive floats.
`image-altitude`	Float	The curated z position of image acquisition. Use this field when the camera is *above the sea surface* (else use `image-depth`). Then the values are positive floats. See `image-longitude` for encoding details.
`image-coordinate-reference-system`	String	A unique identifier for the coordinate reference system. Something like "EPSG:4326". This value most likely is static and should be put to the `image-set-header` part.
`image-coordinate-uncertainty-meters`	Float	The average, i.e. static, uncertainty of x,y,z, coordinates in this dataset, given in meters. This value can be computed from the navigation data curation or estimated. This value most likely is static and should be put to the `image-set-header` part.

Tip: Make your navigation data curation procedure output these values for you automatically. You can use the MarIQT python library to help you with that.

6. Data Managers provide PID information for the image data. → FAIR

Result: *Information for the fields* `image-set-uuid`, `image-set-handle`, `image-uuid`, `image-hash-sha256`.

Info: Persistent identification (PID) information is essential to make image data FAIR. Only by incorporating unique and persistent identifiers can image data be discovered for display in data portals, be accessed by users and tools without manual interference and be re-used for novel scientific discoveries.

`image-set-uuid`	String	A UUID (Universally Unique Identifier - Version 4: Random) for the entire image set. You can create this yourself by using any UUID generation tool. The random version is (almost) guaranteed to be globally unique. Warning: contrary to all other fields this field and `image-uuid` are not linked. They contain different values, and both have to be available!
`image-set-handle`	String	A handle URL to access a landing page to the image data. This landing page *may* link to additional resources where image data or metadata may be downloaded. The landing page has to be guaranteed to remain available indefinitely. You can use a DOI here if you have one for the data set. Should you run your own handle server it may be a good idea to use the `image-set-uuid` within the handle URL of this data set.
`image-uuid`	String	A UUID (Universally Unique Identifier - Version 4: Random) for one single image file (photo or video). This is ***the only field that has to be incorporated into the image file as a metadata field*** (e.g. into the EXIF header for jpegs). Warning: contrary to all other fields this field and `image-set-uuid` are not linked. They contain different values, and both need to be available!
`image-hash-sha256`	String	A SHA256 hash to represent the whole file (***including the image-uuid in its metadata!***) to verify integrity on disk. A hash is like a fingerprint of the file as it is computed from the file's byte content. Using hashes allows to make sure that a file has not gone corrupt or that a particular file is actually the version of interest. Checking the integrity of a file with hashes requires, that the byte content does not change. It is therefore absolutely essential, that the UUID is written to the image file's metadata header before the hash for that file is computed!

Tip: Convince your data management team to conduct this task (including adding the uuid to a file's metadata) for you.

iFDO capture (recommended)

7. Scientists provide scientific information on the image set. → FAIR

Result: *Information for the fields* `image-spatial-constraints`, `image-temporal-constraints`, `image-target-environment`, `image-objective`.

Info: Providing descriptions of the scientific framework of an image set allows re-users to assess the constraints of a data set. E.g. a dataset from an intertidal zone might not be of relevance to a user looking into abyssal ecology.

`image-objective`	Text	A general description of the objective(s) of the study that led to the acquisition of this specific image set. This may include biological, geological, environmental aspects and study design.
`image-target-environment`	Text	A description, delineation, and definition of the habitat or spatial environment of study, including boundaries of such. This is the *target* spatial environment in opposition to the actual acquisition locations.
`image-target-timescale`	Text	A description, delineation, and definition of the period, interval or temporal environment of the study. This is the *target* temporal environment in opposition to the actual timing of acquired data.
`image-spatial-constraints`	Text	A description / definition of constraints that led to the actual spatial extent of image. This includes boundaries and reasons for constraints (e.g. scientific, practical).
`image-temporal-constraints`	Text	A description / definition of constraints that led to the actual temporal environment (period, interval) of image acquisition. This includes boundaries and reasons for constraints (e.g. scientific, practical).

Tip: Be more elaborate than you want to. It will help yourself later on as well to remember what an image set was about and how it came to be. The documentation at https://www.marine-imaging.com/fair lists more iFDO capture fields that might also be useful to your use case.

8. Scientists provide structured general information on the image data itself. → FAIR

Result: *Information for the fields* `image-acquisition`, `image-quality`, `image-resolution`, `image-spectral-resolution`, `image-capture-mode`

Info: This is structured metadata to categorize image data. It helps discovering data sets and keeping an overview of image data. You can only use the fixed values from the vocabulary for these fields as they are specified in the right description column.

`image-acquisition`	String	`photo`: still images, `video`: moving images, `slide`: microscopy / slide scans
`image-quality`	String	`raw`: straight from the sensor, `processed`: QA/QC'd, `product`: image data ready for interpretation
`image-resolution`	String	The average size of one pixel of an image: `km`, `hm`, `dam`, `m`, `cm`, `mm`, `µm`
`image-spectral-resolution`	String	`grayscale`: single channel imagery, rgb: three channel imagery, `multi-spectral`: 4-10 channel imagery, `hyper-spectral`: 10+ channel imagery
`image-capture-mode`	String	Whether the time points of image capture were systematic (`timer`), human-triggered (`manual`) or both (`mixed`).

Tip: Suggest more categories to the MareHub group on videos / images to expand the vocabulary for your needs.

9. Scientists provide structured operational information on the image data itself. → FAIR

Result: *Information for the fields* `image-deployment`, `image-navigation`, `image-scale-reference`, `image-illumination`.

Info: This is structured metadata to categorize image data regarding operational terms. It helps discovering data sets and keeping an overview of image data. You can only use the fixed values from the vocabulary for these fields as they are specified in the right description column.

`image-deployment`	String	How the sequence of images was created. `mapping`: planned path execution along 2-3 spatial axes, `stationary`: fixed spatial position, `survey`: planned path execution along free path, `exploration`: unplanned path execution, `experiment`: observation of manipulated environment, `sampling`: ex-situ imaging of samples taken by other method.
`image-navigation`	String	How the navigation data was recorded. `satellite`: GPS/Galileo etc., `beacon`: USBL etc., `transponder`: LBL etc., `reconstructed`: position estimated from other measures like cable length and course over ground.
`image-scale-reference`	String	How the image scale and area was computed. `3D camera`: the imaging system provides scale directly, `calibrated camera`: image data and additional external data like object distance provide scale together, `laser marker`: scale information is embedded in the visual data, `optical flow`: scale is computed from the relative movement of the images and the camera navigation data.
`image-illumination`	String	How the scene is illuminated. `sunlight`: the scene is only illuminated by the sun, `artificial light`: the scene is only illuminated by artificial light, `mixed light`: both sunlight and artificial light illuminate the scene.
`image-marine-zone`	String	Where the images were acquired. `seafloor`: images taken in/on/right above the seafloor, `water column`: images taken in the free water without the seafloor or the sea surface in sight, `sea surface`: images taken right below the sea surface, `atmosphere`: images taken outside of the water, `laboratory`: images taken ex-situ.

Tip: Suggest more categories to the MareHub group on videos / images to expand the vocabulary for your needs.

10. Scientists provide technical information on the image data itself. → FAIR

Result: *Information for the fields* `image-area-square-meter`, `image-pixel-per-millimeter`, `image-meters-above-ground`, `image-acquisition-settings`.

Info: This is metadata to quantify the detailed position of the camera and the resulting resolution of the image data.

`image-meters-above-ground`	Float	Distance of the camera platform to the seafloor in meters.
`image-pixel-per-millimeter`	Float	Resolution of the images in pixels / millimeter. That value is identical to the value given in megapixel / square meter.
`image-area-square-meter`	Float	The footprint of the entire image in square meters.
`image-acquisition-settings`	JSON	All the information that is recorded by the camera in the EXIF or IPTC or other metadata headers. As a dictionary. This usually includes ISO, aperture, etc.

iFDO content (optional)

11. Scientists compute feature descriptors for the images. → FAIR

Result: *Information for the fields* `image-entropy`, `image-particle-count`, `image-average-color` *etc.*

Info: Making the visual content of image data accessible can be achieved by encoding the visual data itself by feature descriptors (e.g. entropy, average colour, MPEG7 descriptors). It is expected that many more domain-specific feature descriptors will be added in the future.

Tip: Use the basic `image-entropy` and `image-average-color` features to provide a simple method for data visualization (e.g. in data processing reports). This can e.g. help validate that your acquisition time is correct by correlating these image features to other values.

12. Scientists provide semantic annotations for the images. → FAIR

Result: *Information for the fields* `image-annotations`, `image-annotation-labels`, `image-annotation-creators`.

Info: Image annotations are mighty powerful! They provide the link between stupid pixel information and human knowledge. Annotations are encoded by a group of pixels of an image, a semantic label, and a reference to the annotator.

Tip: See the online documentation for more details. Annotation information can be created by various tools. See the MarIQT converters to incorporate annotations created by BIIGLE or OFOP.

Compilation phase (required)

13. Scientists compile all the information into one single iFDO file for publication. → FAIR

Result: *An ASCII file containing all image metadata stored alongside the image data.*

Info: Compile all available metadata fields from all three sections (core, capture, content) into one human- and machine-readable iFDO file. Inside this file, create an “image-set-header” part for those values that are defaults for the entire dataset and one “image-set-items” part for those fields that are not. See the appendix for an example of a compiled iFDO file.

Tip: Use the MarIQT Python library and the proposed folder structure to organize image-derived metadata and to make the entire iFDO creation process simple. And convince your technicians or robotics teams to incorporate iFDO creation right into the data acquisition process itself.

Appendix:

Example iFDO file:

```
image-set-header:
    image-set-uuid: 2a2360e9-a5ec-4ad2-be04-0ea0b4cbdc58
    image-set-handle: 20.500.12085/2a2360e9-a5ec-4ad2-be04-0ea0b4cbdc58@data
    image-set-name: SO268-1_21-1_GMR_CAM-23
    image-context: Mining Impoact2
    image-project: SO268-1
    image-event: 21-1
    image-platform: SO_OFOS-1
    image-sensor: GMR_CAM-23
    image-coordinate-reference-system: EPSG:4326
    image-type: photo
    image-creators:
        - name: T. Bodur
          orcid: 0000-0002-1825-0097
    image-pi:
        name: Y. Bodur
        orcid: 0000-0002-1825-0097
    image-license: CC-BY
    image-coordinate-uncertainty-meters: 13.42
    image-event-information: Towed camera deployment to assess the health status of …
    image-item-identification-scheme: PROJECT_EVENT_SENSOR_DATETIME.jpg
    image-curation-protocol: Navigation data smoothed and splined (see navigation sensor protocol
          for details) and assigned to imagery by timestamp. Coordinate uncertainty is given by
          standard deviation from navigation smoothing. Imagery without content (all black) due
          to lamp failure were removed manually.
    image-acquisition-settings: Camera set to auto mode for ISO, f-number and exposure time
image-set-items:
    SO268-1_21-1_GMR_CAM-23_20190513_131415.jpg:
        - image-uuid: 9999ba88-1a20-4efe-a0ac-6b4233490ad6
          image-hash-sha256: 83f30eb35d1325c44c85fba0cf478825c0a629d20177a945069934f6cd07e087
          image-datetime: 2019-05-13 13:14:15.0000
          image-longitude: -123.854637
          image-latitude: 42.133426
          image-depth: 4230.3
          image-pixel-per-millimeter: 12.1
          image-meters-above-ground: 1.3
          image-coordinate-uncertainty-meters: 4.2
    SO268-1_21-1_GMR_CAM-23_20190513_131416.jpg:
        image-uuid: 1c266c00-33e7-4e69-bc9a-f90fb1bce6d0
        image-hash: 27c3585560f93a78995a038b5970a002315d2b525b999a24a1d13a5c5e5520f6
        image-datetime: 2019-05-13 13:14:16.0000
        image-longitude: -123.854638
        image-latitude: 42.133427
        image-depth: 4230.4
        image-pixel-per-millimeter: 12.1
        image-meters-above-ground: 1.4
    SO268-1_21-1_GMR_CAM-23_20190513_131417.jpg:
        ...
```

References:

- SOP „iFDO creation“ supplement: https://doi.org/10.5281/zenodo.5683082
- FAIR marine images: https://marine-imaging.com/fair

Glossary:

DMP: Acronym for Data Management Plan – a living document that collects information on planned and acquired datasets as well as models, software and more

FAIR: Acronym for Findable, Accessible, Interoperable, Reusable – describing the leading principle in data management to increase the value of data

iFDO: Image FAIR Digital Object – a standardized format for the description of image metadata

Image: Photo (still image) or video (moving image)

RDM: Acronym for Research Data Management – referring to the process and also the team of highly-trained people

SOP: Acronym for Standard Operation Procedure – a static or dynamic document describing a sequence of tasks acting on data entities to reach a defined goal

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Abstract: This Standard Operating Procedure document describes how standardized metadata for marine research images shall be structured. This includes photos (still images) and videos (moving images). The goal of this document is to enable scientists to provide FAIR metadata for image data.

Note: This SOP provides a general overview of the topic and includes technical specifications. You may need to adjust it to your needs to include specific information on your infrastructure to adapt it to your institute / workflow.

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License: CC-0

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Revisions:

Version	Date	Author	Comment
v1.0.0	2021/11	Timm Schoening	Initial draft of a public text version of this SOP. Compiled from discussions in the MareHub AG Videos/Images.