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D4.6 Research data catalogue
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Abstract	This deliverable describes the catalogue of research objects identified in the project. Also, a methodology to characterize these objects has been developed to facilitate this work, adapting it to the necessities of citizen science projects.
Keywords	Research objects, citizen science

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How to quote this document

Gonzalez, E et al. . (2020) Research objects catalogue (first version)

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EXECUTIVE SUMMARY

This deliverable contains the first version of the research objects catalogue. A research object allows to represent the knowledge generated in different investigations carried out in the project, specially within the pilots. A graphical notation has been developed to visualize this knowledge using diagrams. This can be especially useful for both researchers and citizens.

Researchers can monitor the status of their research, it means, identifying resources they need or resources that are not linked with other elements of their research. Thus, they can have a *big picture* of the outputs generated by their research and the relation among them. It benefits the reproducibility of the research. Also, it allows external researchers to identify resources that can be relevant for their own investigations, promoting the reusability of resources .

Citizens can understand easily and find the different elements generated/used in the investigation, increasing the transparency and the replication of it. This is very relevant because it can facilitate the adaptation of a particular investigation to another domain or location. This model has the potential to be exported to other CS projects.

As a result of this deliverable, a methodology has been developed to characterize and deploy research objects. Particularities of Citizen Science projects have been taken into account to design this methodology. Generally the complexity of CS projects is not excessive, unlike big research projects.

The research objects are deployed in a platform named ROHub which allow us to manage the research object lifecycle, as well as provide us with interesting features such as versioning, semantic annotation and machine access through an API.

Our plan is to integrate this catalogue with our Open Data Portal. It allows us to represent the research objects in a context more adapter to citizens.

1 INTRODUCTION

Open Science promotes a change of paradigm to make available the outputs of scientific activity to different stakeholders: education, research institutions, private sector and the society in general. In the past, the dissemination of these activities has been limited to scientific publications.

With the introduction of the new technologies, the role of data, software and protocols has become more relevant in the description of scientific experiments. Hence, to support the Open Science principle of reproducibility (and transparency), all the components needed for reproducing the experiment have to be identified, catalogued and provided with instructions.

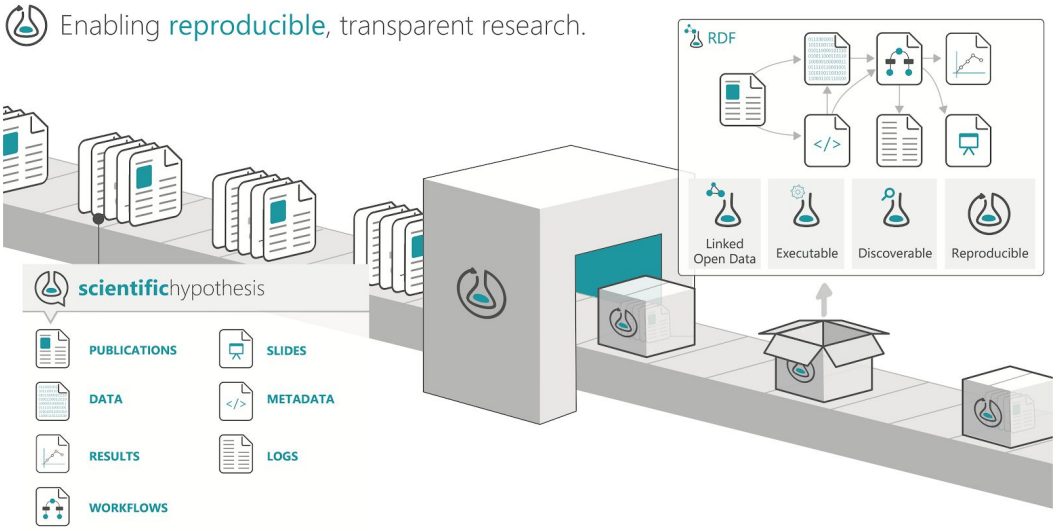
A Research Object (RO) is an aggregation of digital objects that packages resources describing a research activity. ROs can improve reuse and reproducibility[1] in a scientific process by:

- Supporting different types of researching resources such as publications, data, code, slides, images, videos, etc...
- Publishing these collections of resources as a shareable and cite-able resource
- Enriching these resources with additional information (metadata and vocabularies).

This research object will evolve in time (when more outputs will be aggregated to the RO)

Figure 1 depicts the concept of a research object. A RO is not simply a collection of elements, but a graph describing also the relations among the different digital resources packed in it. Generally, an ontology or vocabulary is adopted to describe these relations in a standardized and interoperable manner.

[1] https://www.researchobject.org/



Source: https://www.researchobjects.org

Figure 1: Research Object

In chapter 2, the methodology followed to identify the research objects in the project is described. It is composed by two stages: 1) to characterize the research objects and 2) the creation and deployment process

In chapter 3, all steps followed in this stage and the results produced by our methodology are described. In this first version of the catalogue, our main goal has been the creation of the research objects of the pilots. For it, diagrams have been used to facilitate the interaction with them. As can be seen, depending on the maturity of the pilot, will have more or less resources.

In chapter 4, ROhub, the platform for creating and deploying the research objects is described. This platform implements the main features of the research object lifecycle, such as creation, versioning and publication. Also, it is possible to add semantic annotations to research objects, which improves the quality of them and their future interoperability with other components.

Finally, in chapter 5, conclusions and future lines are presented.

2 METHODOLOGY

To build the Research Objects Catalogue we have developed and applied the following methodology. The process consists of two stages:

1) To identify the resources and the relations between the elements that compose each research object
2) To create and deploy the research objects on a platform where they can be shared and cited.

Stage 1: Research objects characterization

ACTION is a project where different pilots are accelerated to improve their results (including their scientific outputs). The complete list is available on the ACTION website[2].

The first design decision that should be made is related to the scope of a research object. Indeed, a RO can represent the knowledge of a pilot or a specific research/experiment inside the pilot. In the RO community, there is not a clear consensus on what approach should be followed. In the ACTION Research Object Catalogue, each research object models a single experiment performed within a pilot. An experiment can be defined as a procedure to validate/refute a hypothesis, generating a set of data and analyzing them to probe the validity of the hypothesis.

As discussed in chapter 3, most of the ACTION pilots have only one experiment and, therefore, a single associated RO. This is because normally, citizen science projects are composed of simple scientific activities. This research object will evolve in time (when more outputs will be aggregated to the RO). Generally, a research object has a lifecycle that ends when the experiment finishes. We will see in chapter 4 how different versions of research objects can be created.

Once clarified the scope of a RO, it is important to identify the relevant outputs generated in each pilot. As stated in the D4.5 Open Data Portal deliverable, most of the produced results are published in Zenodo[3]. A specific community[4] was created in Zenodo for the ACTION project and additional communities for some of our pilots.

Nevertheless, some pilots host resources in other repositories/services such as Github, GBIF, Youtube etc… To define complete ROs, specific calls were planned for each pilot to avoid relying only on the material archived on Zenodo and to define a comprehensive list of resources available.

Before the scheduled calls, a presentation was prepared to describe the concept of a research object to the leaders of each pilot[5].

[2] https://actionproject.eu
[3] https://www.zenodo.org
[4] https://zenodo.org/communities/actionprojecteu
[5] https://doi.org/10.5281/zenodo.4432410

To start characterizing each research object a graphical notation was adopted to represent the resources in the RO and the relations among them. A graphical annotation to represent ROs helps in visualizing them and it is useful for people not familiar with these concepts. Figure 1 depicts this notation.

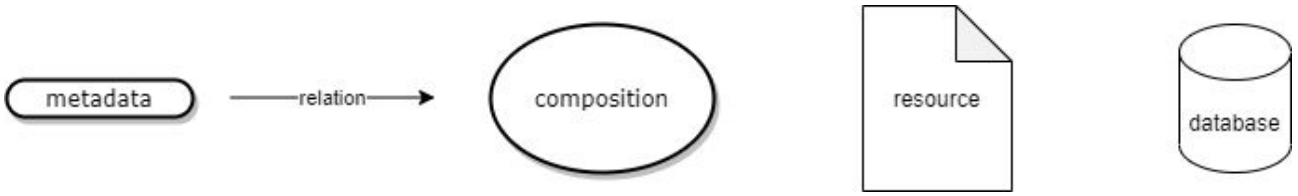


Figure 2. Graphical notation

The elements are:

- Metadata: It is information that describes a resource such as digital objects identifiers, url of the resource, name of authors, etc …
- Composition. It represents an aggregation of resources of metadata. For instance, if you want to group all the authors of a paper, you can use this element like a node root.
- Relation: It expresses the kind of relation between the resources of the research object.
- Resource: It is any kind of digital object published on a repository. These digital objects are the output of the research. The collection of them form the research object.
- Database: It represents a database in the system. Normally, it is not public.

Draw.io[6] is the collaborative tool to build diagrams chosen to describe ROs in this first stage. The platform has a wide catalogue of templates that can be adapted to different kinds of diagrams, and allows exporting generated diagrams using different image formats. The collaborative editing feature has been very useful because it allowed us to create the RO representation collaborating with different users.

During the organized calls, the participants for each pilot, were guided in the identification of the different resources generated in their experiments and the relations among them. With the support of the Draw.io tool, a different diagram was generated for each RO (see Section 3). These diagrams were finalised and refined lately by the ACTION WP4 team.

At this point, we have modeled the ROs of the pilot but what happens to the outputs (WPs deliverables) generated in the project?

Some of the deliverables, especially the reports, could contain other resources besides the document, so it may make sense to add them as research objects.

To characterize the research objects, a set of questions have been created to identify the different objects of the experiment and the relationship between them.

- Have you used/generated **datasets**? Specify urls and explain the relation with the deliverable

[6] https://draw.io

- Have you used/developed **software**? Specify urls and explain the relation with the deliverable
- Have you written a **paper** based on this deliverable? Please, specify urls and explain the relation with the deliverable
- Have you created a **video** to explain this deliverable? For example, a recorded session from a conference. Please, specify urls and explain the relation with the deliverable
- Have you created a **presentation** to show the results of this deliverable? For example, on a conference, workshop, etc… Please, specify urls and explain the relation with the deliverable
- Relate this deliverable with the **Participatory Research Lifecycle** (https://zenodo.org/record/3687582#.X7UX1xNKi8o). Please, specify urls and explain the relation with the deliverable

The analysis of this table shows that for the moment, these documents haven't enough resources associated yet so we decide not to include them as research objects in this version. However, we will consider doing it if they will transform into a scientific publication in the future.

Stage 2: Research objects creation and deployment

Once the diagrams and the design of the research objects are finalised, they have to be deployed to be made findable and accessible. The platform chosen has been ROHub[7]. Basically, it allows to translate the information present in the diagrams to the format adopted by the platform to represent ROs. We will describe the platform and the process followed in chapter 4.

Besides the use of ROHub, we have defined the relationship between the digital objects in Zenodo too. For this purpose, we have adopted a special metadata field in Zenodo named *Related Identifiers*. We can define the following relationships between them:

- isCitedBy
- cites
- isSupplementTo
- isSupplementedBy
- isNewVersionOf
- isPreviousVersionOf
- isPartOf
- hasPart
- Compiles
- isCompiledBy
- isIdenticalTo
- isAlternateIdentifier

These relationships don't cover all possible relations among the resources but they cover most of them. Note that the name of the relations coming from the pilots' teams so they haven't been

[7] https://www.rohub.org/

systematized and standardized following a vocabulary or ontology. This was done on this purpose to facilitate the process of research objects with the pilots.

During the interview with the pilots' leaders, they suggested some words to describe the relations between the objects. These words have been adapted to the vocabulary used in Zenodo and RoHub for describing the relationship between the objects. Take into account that in Rohub, the objects are described semantically, so they must follow an specific vocabulary or ontology.

3 RESEARCH OBJECT CATALOGUE

This chapter describes the research objects identified in the project using diagrams. It describes the steps and results of the first stage of the methodology described in chapter 2. These diagrams have been designed with the support of the pilots through a co-creation process. As a general comment, the presented diagrams show the resources published at the moment of publishing this document, not the resources that will be collected in the future execution of the pilot/experiment.

The chapter describes first the ROs designed for the original pilots of ACTION (Section from 3.1 to 3.5), and then the ones corresponding to the pilots incorporated in the first open call (Section 3.6, 3.7, 3.8).

The projects *Water for future* and *WOW nature* don't have diagrams because they were postponed due to the coronavirus pandemia. Nevertheless, they participated in the calls and their research objects will be designed and created in the second open call.

3.1 STREET SPECTRA

Street Spectra is a citizen science project to map and characterize public lighting sources. Volunteers use a low cost diffraction grating on top of their smartphones' camera to take pictures of the street lamps and their emission spectra. The resulting images allow street lamps classification by comparison with example pictures of well known lighting systems.

The diagram describing the designed RO can be found here:
https://drive.google.com/file/d/11tmuuQ4z6FdyiowIt07Dznt0Hb_4vJmp/view?usp=sharing

Figure 2 depicts the relationship between the different resources published. This is one of the most complex research objects of the project due to the number of data sources involved in it.

We have three different data sources:

- An application developed using the platform Epicollect. The result of this application is a set of images collected by citizens and a CSV with information associated such as location and type of lamppost. More information about this application can be found on deliverable *D4.2 Lifecycle aware CS template* (see the relation in the diagram).
- An application developed using the platform Zooniverse. The result of this application is a classification of the images taken by the previous application done by citizens. More information about this application can be found on deliverable *D4.2 Lifecycle aware CS template* (see the relation in the diagram).
- A mobile application that is in a test phase but will be released on M26. The results will be images of streetlight spectra classified by citizens.

This research object has a deliverable (tutorial) to teach citizens about how to manage the first application and to define the theoretical framework of spectra identification. It is written to be read mainly by teachers who want to explain the experiment/project to their students.

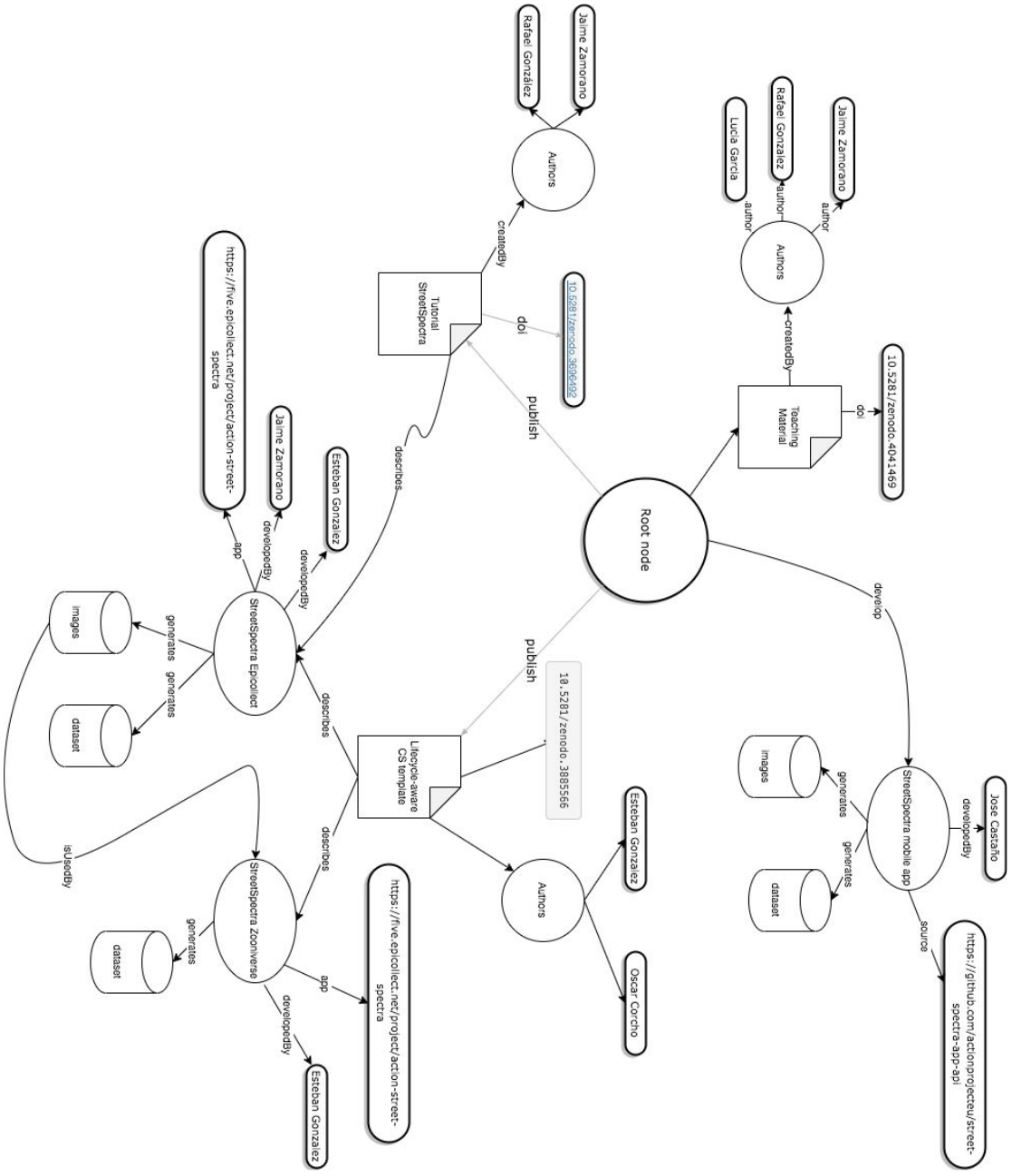


Figure 3. Street spectra research object diagram

3.2 STUDENTS, AIR POLLUTION AND DIY SENSING

The pilot gives high school students in Oslo and the larger Oslo area the opportunity to design and carry out their own air quality projects, using an off-the-shelf air quality sensor platform. The aim is to (i) create awareness about the sources of air pollution, (ii) to make the students think of ways to reduce both emission and exposure, and (iii) to teach them scientific working methods. A Nova

SDS011 sensor is used for measuring PM2.5 and PM10 and it transmits data to an Arduino board. The data can be retrieved through an SD card.

The diagram describing the designed RO can be found here:
https://drive.google.com/file/d/1IJU3H5Rjnt2KwDFmVmMSCHz2vgwGb3lZ/view?usp=sharing

Figure 4 depicts the research object of this pilot.

In this case, the data source is a device built for the students. Looking at the diagram, the reader can see the url of the device, the sensor used (NOVA SDS011) and the firmware deployed to make the measurements and to generate the dataset. These datasets have been published on Zenodo both in the ACTION community and pilot community.

To build these sensors and to interpret the results, a presentation (*Forskningsprosjekt luftforurensning*) was showcased to the students and teachers in the classroom.

Once the measurements were taken, the students presented their works creating a collection of posters (see posters bubble in the diagram). The complete results were discussed in a deliverable, also reported in the diagram.

The RO notation used in the diagrams allows expressing the relationships between the different elements of an experiment but can not represent the sequence of the steps. This aspect can be described adding to the research object a workflow modelling this sequentiality.

Similar elements, like posters, are grouped in a single node to make the diagram more understandable for citizens.

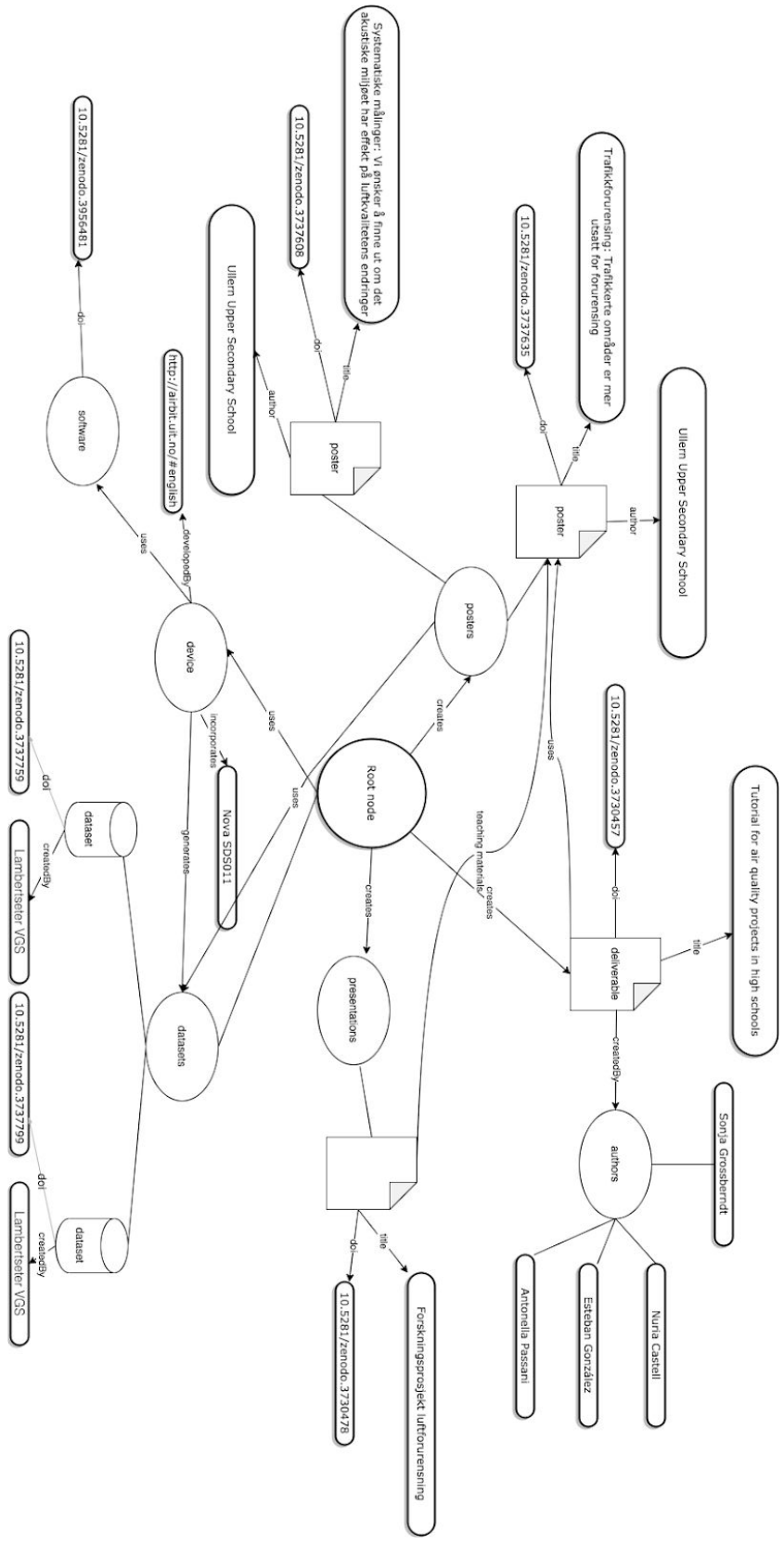


Figure 4. Students and air pollution research object diagram

3.3 TATORT STREET LIGHT

The project will invite amateur entomologist to participate in the research as well as discuss and analyze insect behavior to street lights and develop ideas for sustainable solutions for night time illumination

The execution of this pilot started two months ago and currently no digital resources have been published yet. Nevertheless, the leaders of the pilot participated in all the calls related to research objects and they are aware of the elements needed to create them. This research object will be created as the outputs are generated. It will be presented in the next version of the catalogue.

3.4 LOSS OF THE NIGHT

The Loss of the Night App invites citizen scientists worldwide to take part in a research project that measures light pollution by using the human visual system as a light meter. Specifically, participants are asked to look for specific stars, and report if they can see them from their location.

At this moment, this pilot has not published the datasets or the source code of the software used to generate the data. The plan is to publish the results in the next months, so we will start the process to create the research object at the same time. It will be presented in the next version of the catalogue.

3.5 CITIZEN SCIENTISTS, DRAGONFLIES AND PESTICIDES

Water quality has improved quite a lot in the second half of the last century and dragonflies, as aquatic insects, have recovered the population of dragonflies in this period. However, recently it has been observed that numbers have started declining again and this seems to be mostly the case with the common species outside of nature reserves. This observation is made possible by the hundreds of volunteers counting dragonflies every two weeks on fixed transects.

At this moment, the project has only published a tutorial for water samples collection. For this reason, it does not make sense to create a research object for the pilot at the present moment. A call with the coordinator of the pilot was organized to analyze the kind of outputs that they are going to generate and the possibility of defining in the future a research object to represent them. The pilot will define a dataset with the results of the water samples analysis and a final report.

3.6 NOISE MAPS

NOISE MAPS allows citizens to generate and to analyse urban sound data, empowering communities to take action to reduce unwanted noise and protect the local sonic heritage. The pilot

builds on existing cultural practices of collective documentation of the sound heritage of neighbourhoods (Mapa Sonor). Thanks to the project activities citizens will be able to filter unwanted noise out from authentic, locally unique sounds, thus allowing communities to take action to preserve their sonic heritage.

The diagram describing the designed RO can be found here:
https://drive.google.com/file/d/1S1htElFPdr_F8MpH2tfSvIg9xeeWtUpG/view?usp=sharing

Figure 5 depicts the diagram of this research object.

For this pilot, the data source is a collection of sounds recorded with a special device whose description and firmware can be found in the links shown in the diagram. Only some of these sounds are uploaded to the sounds platform Freesound[8]. This is because these sounds can contain personal conversations so a curation process is needed.

All sounds recorded are processed with an algorithm to detect the sources of the sounds such as kids playing, traffic, schools, etc … The result of this algorithm is a dataset that has been deposited in Zenodo, generating the corresponding DOI. Also, this dataset was uploaded to the ACTION database allowing its visualization through the Grafana[9] platform (*see D4.7 Live Dashboards deliverable*). Moreover, these dashboards were embedded in a geographical platform of the Catalonia Geographical Institute. Both links are shown in the diagram.

[8] https://freesound.org/
[9] https://grafana.com/

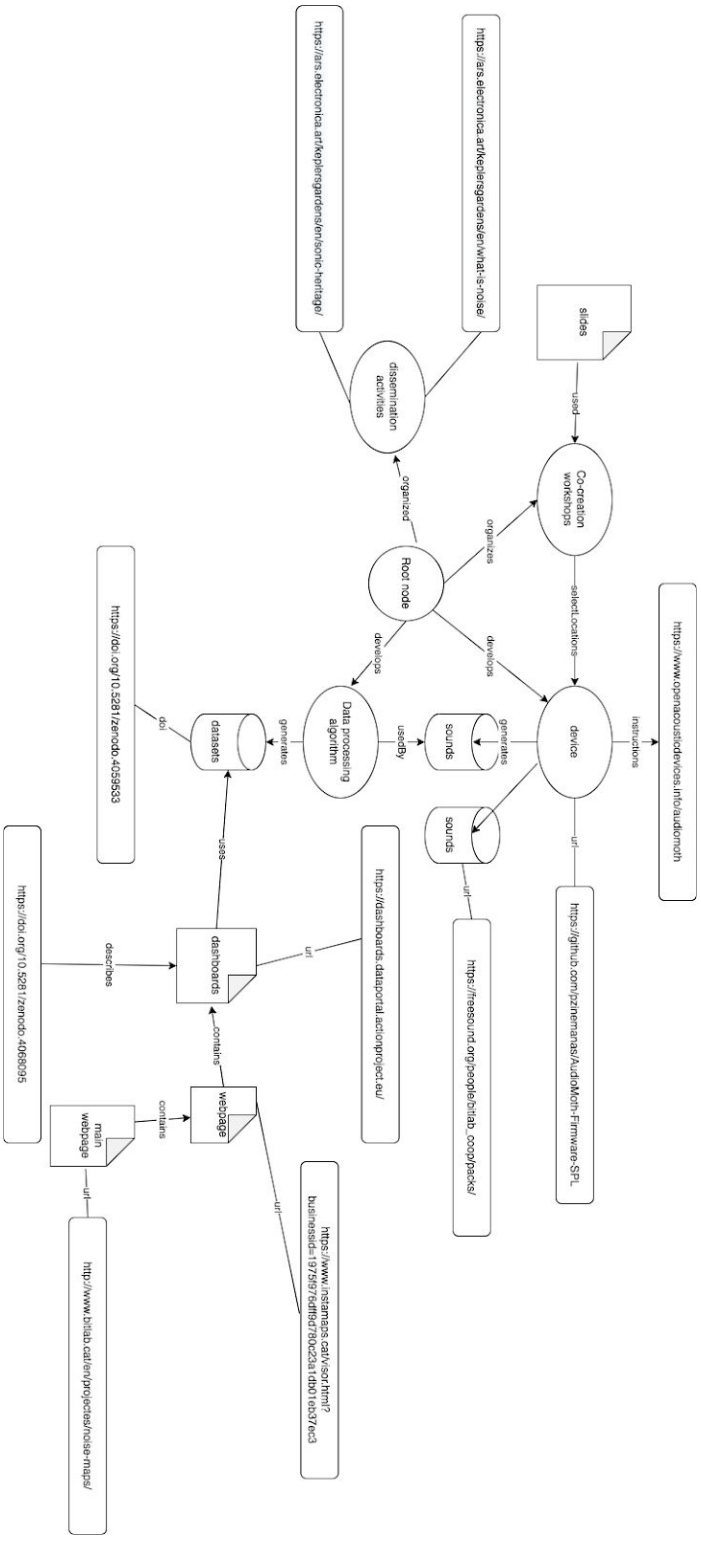


Figure 5. Noise Maps research object diagram

3.7 SONIC KAYAKS

The Sonic Kayak system is a low cost open hardware for gathering and mapping fine-scale marine environmental data, which has not been previously possible to obtain. Data is sonified through an onboard speaker allowing paddlers to seek out areas of interest and gain real time feedback of the data

Figure 6 depicts the research object of the pilot. The diagram can be also found here: https://drive.google.com/file/d/1vxGpUKU-VOIFYOz0jjglYW68scsIJIo9/view?usp=sharing

The project has designed and developed a sensor to measure different parameters of the water. The information related with this development can be found in the links shown in the diagram. Datasets generated by this project were deposited in the Zenodo community created for this purpose. All visualizations were uploaded to FLICKR, in the url specified in the diagram.

Additional resources represented in the research object are: (i) a survey administered by the project and published in the Zenodo community together with the collected results, (ii) material created for dissemination activities and published in the project's blog and in its youtube channel.

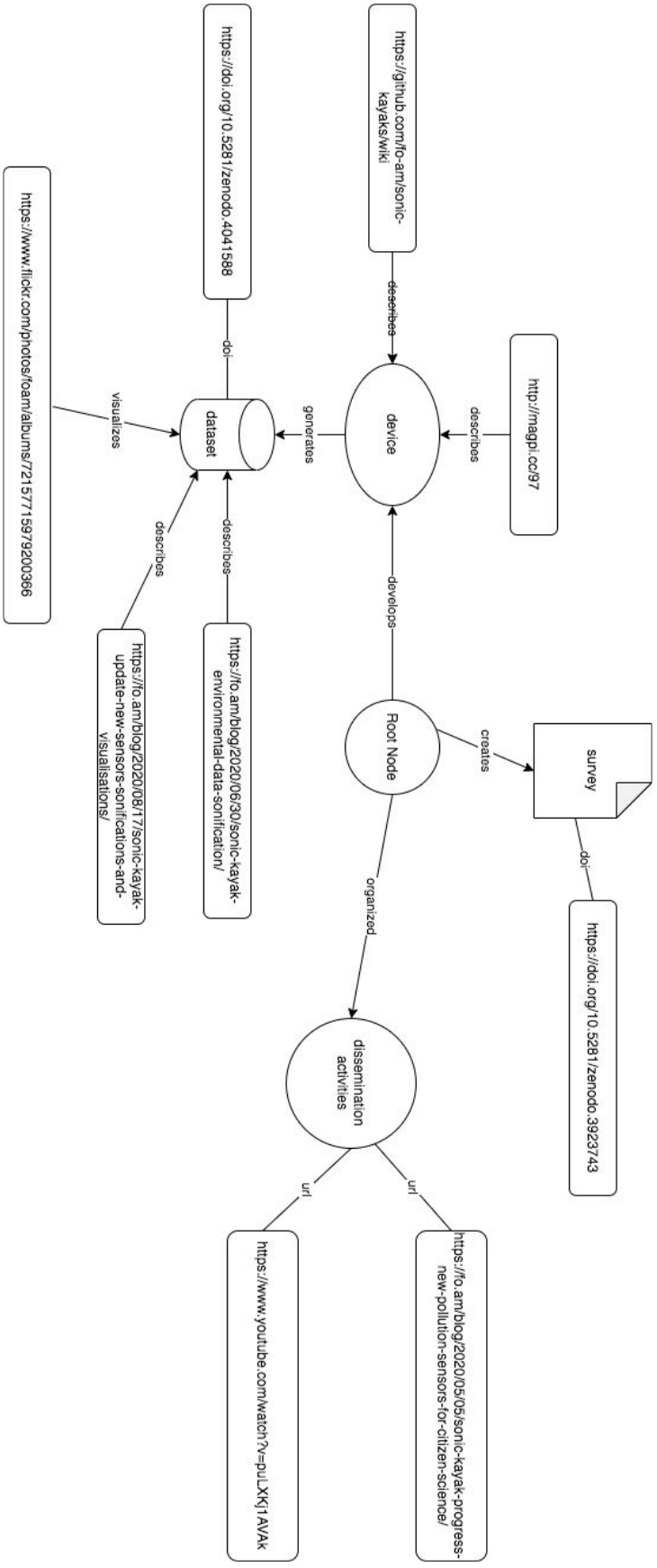


Figure 6. Sonic Kayaks research object diagram

3.8 IN MY BACKYARD

The project aims to understand and map the use of pesticides and fertilizers and sustainable alternative practices in the context of home farming and gardening. Simultaneously, it aims to disseminate information on the topic with the final aim of reducing the use of pesticides and fertilizers.

Figure 7 depicts the research object of In My Backyard. The diagram can be also found here: https://drive.google.com/file/d/1vxGpUKU-VOIFYOz0jjglYW68scsIJIo9/view?usp=sharing

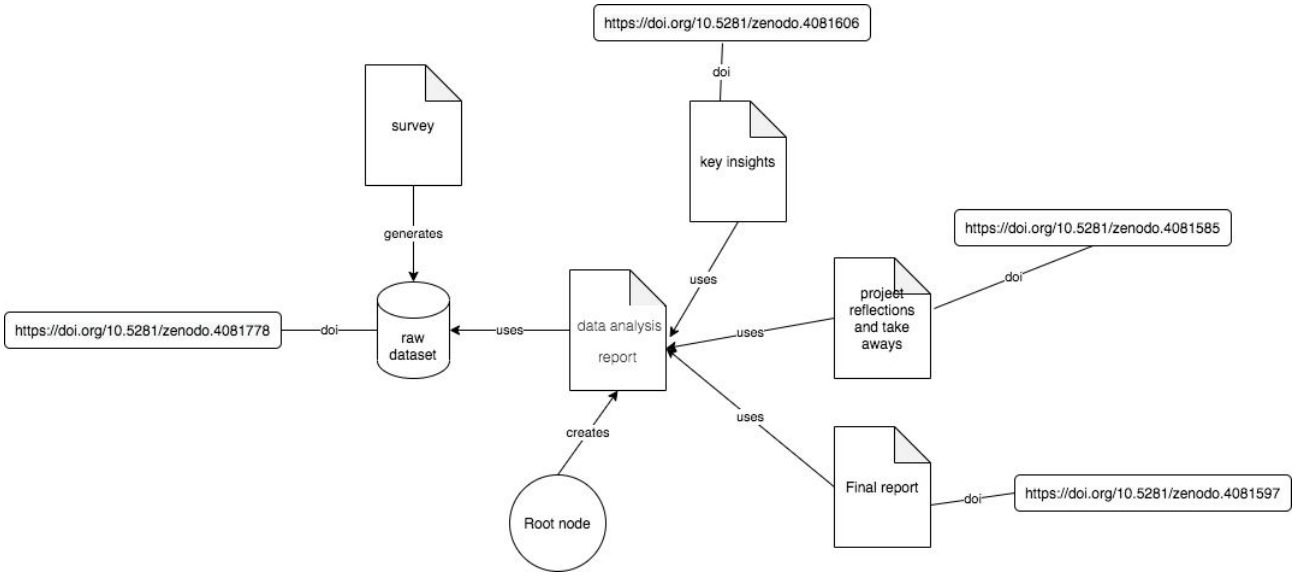


Figure 7. In my backyard research object diagram

In my backyard is based on a survey done to home farmers. The results of this survey, previously anonymized, were published in its Zenodo community. Lately, these data were analyzed by publishing a report.

More documents such as considerations, key insights and the final report were published in the same community.

4 ROHUB: A RESEARCH OBJECT PLATFORM

The previous chapters described the methodology and the outcomes of the co-design activities carried out with the ACTION pilots to define a catalogue of research objects.
As commented in chapter 1, a research object is an aggregation of digital objects related among them that needs to be findable and accessible. To deploy the designed research objects the ROHub platform was adopted.

4.1 Introduction

ROHub is a research object management online platform to preserve and to manage the lifecycle of research objects. ROHub is an open source solution which source code is openly available on Github[10].

One of the most interesting features is that the content of a research object can be interpreted also using semantic annotations[11] to make your resource readable for machines. Although we have not fully taken advantage of this feature for this version of the catalogue, it can be extended in the second version of the catalogue. This feature makes research objects more interoperable and easily consumable in machine to machine (M2M) interactions. The specification of the semantic RO model adopted by ROHub can be found here: http://wf4ever.github.io/ro/.

ROHub provides an API to access the functionalities of the platform. This is a key feature to connect the platform with other systems (see Next steps chapter). Moreover, a SPARQL endpoint is made available in ROHub to execute semantic queries over the research objects that, as mentioned above, can be annotated semantically producing an RDF description of the RO..
Users can upload their resources to the platform and add them to a specific research object. However, we have not used this feature for the particularity of our project. As seen in the diagrams, resources have been deposited in different repositories, particularly in Zenodo. So in our case, the elements that compose the research objects have been aggregated using their DOIs or URLs.

4.2 Features

In ROHub, users can search research objects selecting different criteria: Research area, Creator, Creating date, Type, State, Quality, Contents and Metrics. When the user executes a query, the research objects that fit with the pattern are shown (see Fig 8.).

[10] https://github.com/rohub/

[11] https://www.ontotext.com/knowledgehub/fundamentals/semantic-annotation/#:~:text=Semantic%20annotation%20or%20tagging%20is,or%20topics)%20relevant%20to%20it.

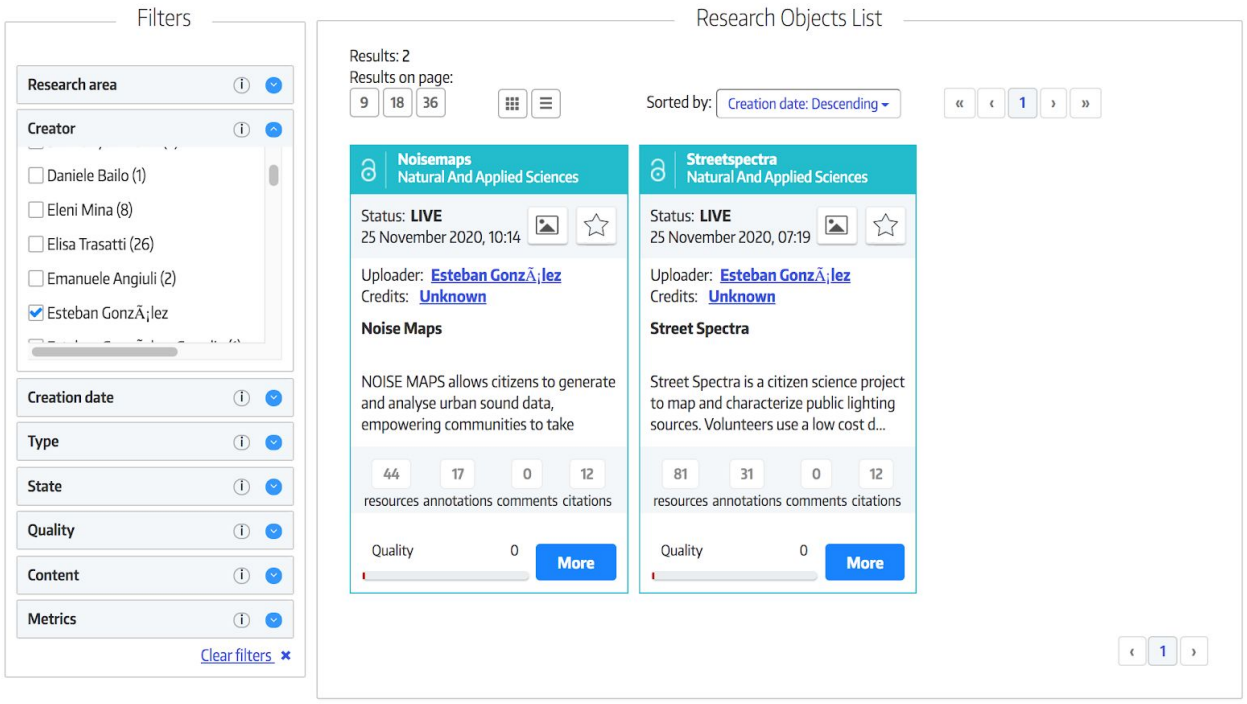


Fig 8. Search component

If the user clicks in one of the research objects, a window with tab panels is shown. Each panel contains relevant information about the research object.

In the *Overview panel,* the user can see general information about the research object such as creation date, title, summary, creator, etc … The values of the metadata fields introduced by the user are automatically annotated using the ontologies adopted by the platform. An example result is shown in Figure 9. The user may add additional annotations but only using the provided ontologies. The elements of the ontologies are suggested through an autocomplete field. Also, these annotations can be defined in the Relations pane to link the different digital objects present in the research object.

The user can also see a list of indicators on the top of the panel. These indicators represent number of views, downloads, number of resources, activity, forks, snapshots, qualities and size.

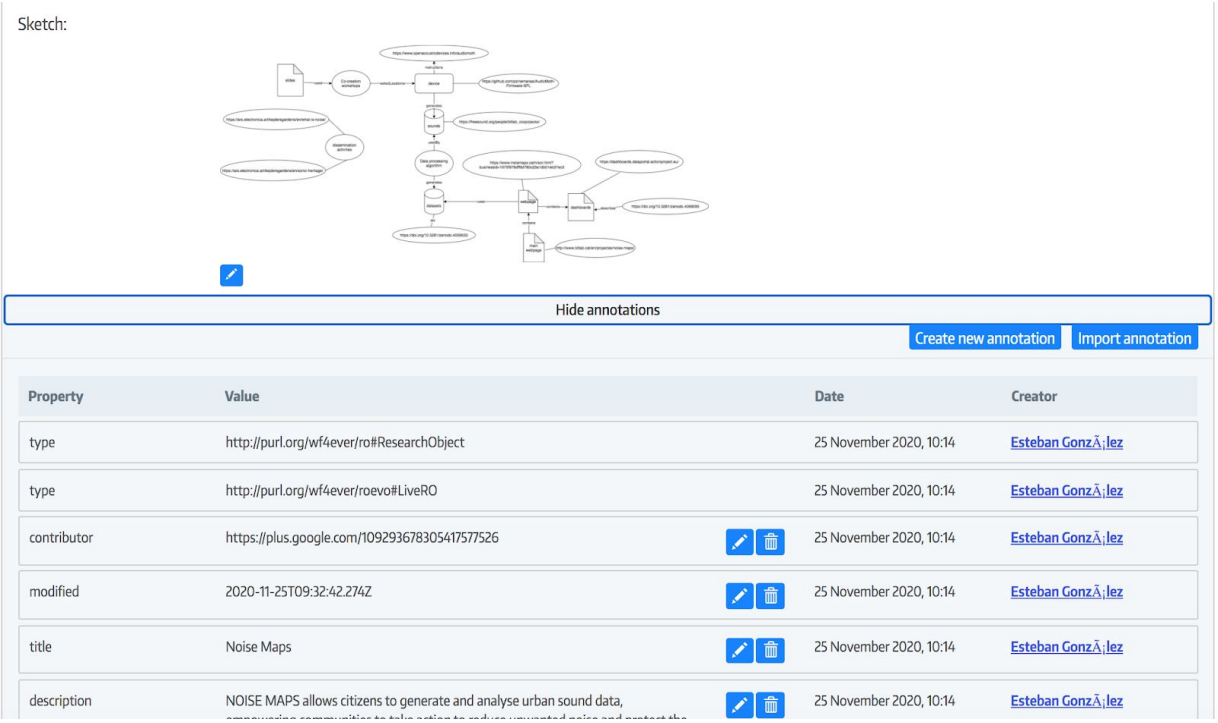


Fig 9. Research object overview

ROHub allows adding a sketch to represent a RO. We used the diagrams created in chapter 3.

In the *Content* panel, the user can see the files that compose the research object. Remember that it is possible to add both physical objects and web links. All these objects are organized in folders, forming an hierarchical structure. Users are free to change this structure. An example is shown in Figure 10.

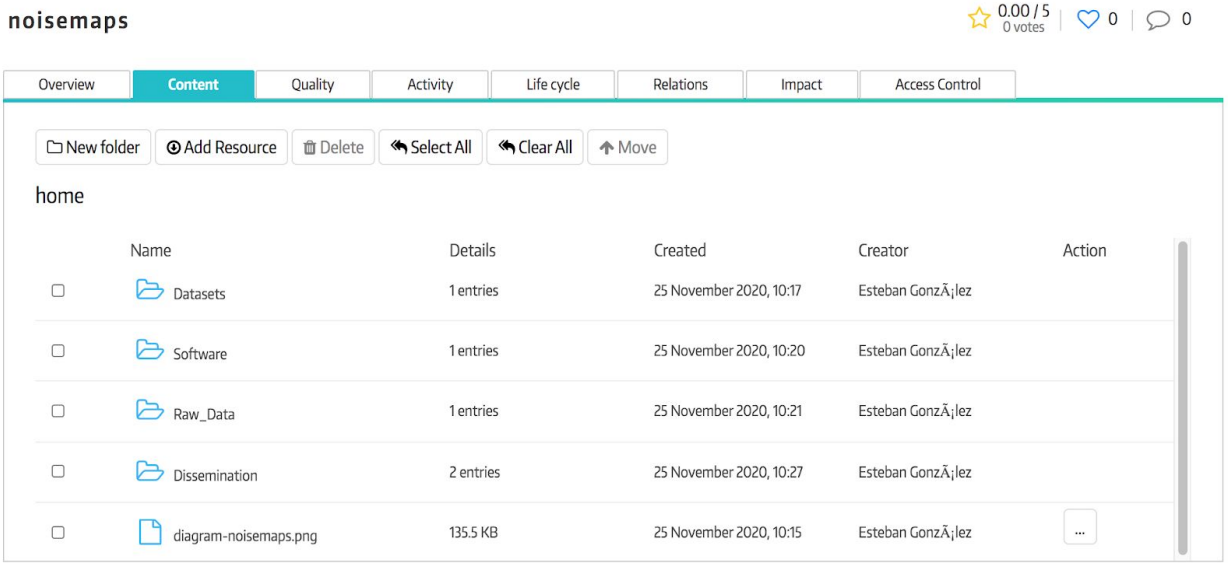


Fig 10. Content panel

As commented in chapter 3, similar documents or resources were grouped in different categories in the defined diagrams. The folder structure can support this representation.

In the *Quality* panel, the user can check the quality of the research object. The quality indicator is calculated based on a list of requirements defined on a RO template. These requirements are checked against the metadata fields provided by the user. Some of these templates are: RO basic requirements, Workflow-centric RO basic requirements, and Earth Science requirements. For example, in the case of the RO basic requirements, the system expects the following elements: title, description, hypothesis, conclusion and annotations.

In the *Activity* panel, the user can track the activity performed for the research object. It includes annotation of the elements, modification of elements, creation of new resources, etc … It is very useful to track the changes on the research object. Note that a research object can be modified by different users.

In the *Lifecycle* panel, the user can see the status of the research object. This is one of the most important features for a research object. In Figure 11 an example is shown considering a complex research object available on the platform.

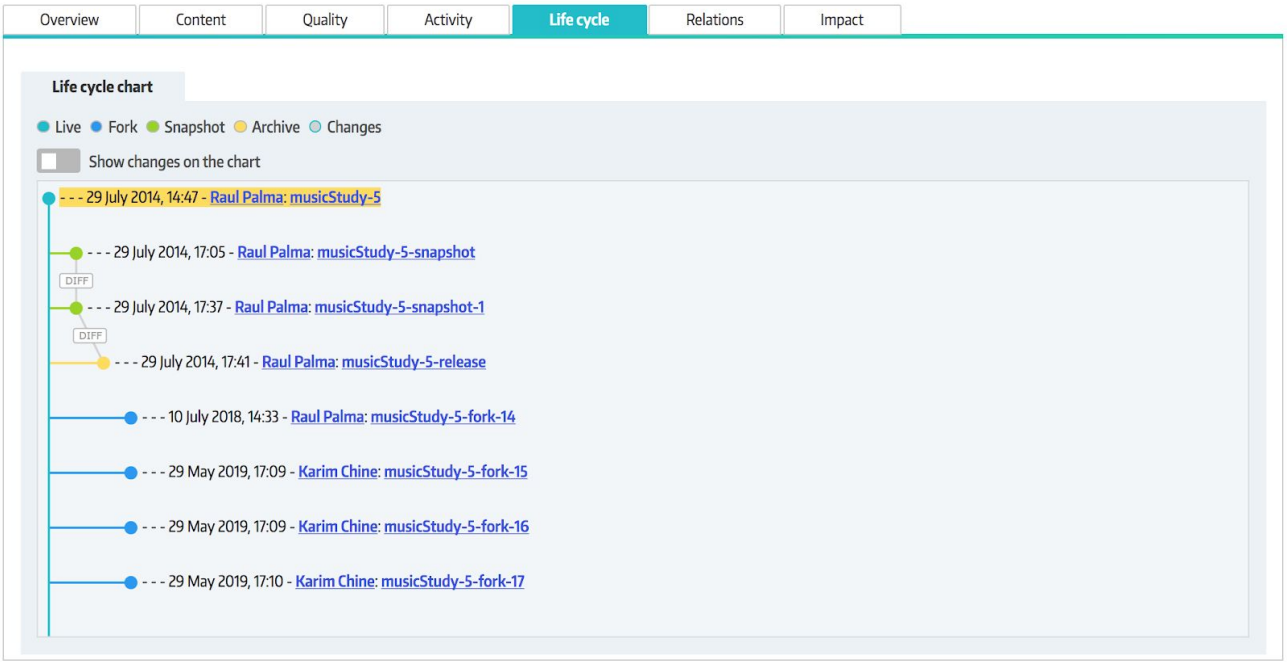


Fig 11. Status panel

Three events can affect the lifecycle of the research object:

- *Fork*. A *fork* clones a research object creating a copy that can be modified independently of the modifications the user does on the original research object. In some way, creates a new version of the RO without blocking further changes in the original. Normally, a user forks a general RO because they want to apply it to a specific domain.

- *Snapshot*. A user can create a *snapshot* of a research object. This is an immutable copy of the content. This copy can be used to share it or generate new versions. This is very relevant in our case because, normally, the experiments of a pilot executed in different years are very similar (same types of resources and relations among them, changes mainly related to the links of the resources).
- *Archive*. Similar to the *snapshot* state, *archive* generates a persistent identifier for the research object. It is also an immutable object.

In the *Relations* panel, users can define the relations between the different resources of a research object. Note that if you want to link with resources of other ROs or you want to use another kind of relations, you will have to use annotations. In fact, these relations are converted in semantic annotations automatically. The list of relations are shown in the following table.

Table 1. List of relations in Relation panel

wasDerivedFrom	wasQuotedFrom	hadOriginalSource
inputSelected	subsequentWorkflow	previousWorkflow
hasInput	hasSubWorkflow	useInput
describedByWorkflow	wasRevisionOf	hasOutput
rootURI	wasOutputFrom	hasWorkflowDefinition

In the *Impact* panel, the user will find a set of statistics to monitor its research object.

Finally in the *Access control* panel, the user can grant permissions to other users to manage the research object. There are two roles: *editors* (write/read) and *readers* (read). Also, the manager can decide the visibility of the research object (*public* / *private*).

At this point, we have analyzed the features of the platform.

4.3 Research Object Catalogue on ROHub

In the following table, we summarize the URLs of the research objects created based on the diagrams of chapter 3.

Table 2. Links of the research objects created in RoHub

Name of the pilot	**URL**
STREET SPECTRA	http://www.rohub.org/rodetails/streetspectra/overview
STUDENTS, AIR POLLUTION AND DIY SENSING	http://www.rohub.org/rodetails/ACTION_air_pollution/overview

TATORT STREET LIGHT	N/A
LOSS OF THE NIGHT	N/A
NOISE MAPS	http://www.rohub.org/rodetails/noisemaps/overview
SONIC KAYAKS	http://www.rohub.org/rodetails/ACTION_Sonic_Kayacs/overview
IN MY BACKYARD	http://www.rohub.org/rodetails/ACTION_in_my_backyard/overview
WATER FOR FUTURE	N/A
WOW	N/A

Some of them are not present because there were not enough elements to define them.

5 CONCLUSIONS

One of the objectives of the WP4 is to implement and integrate the software needed to support the lifecycle of Research Objects. For the creation of research objects, we have applied a methodology based on the collaboration with the pilots. This methodology is composed by two stages as it can be seen in chapter 2. This has been a challenge because, normally, citizen scientists are amateur scientists and not fluent in scientific techniques and methodologies.

The use of a collaborative and a visual tool has shown an effective method to increment the participation and the comprehension of the problem, detecting problems in their research.

The use of ROHub, a platform to manage the lifecycle of the ROs, clearly satisfies the requirements of one of the objectives of this WP.

For the next version of the catalogue, the work will proceed identifying new research objects and generating new versions of these first ROs. Moreover, the outputs of the new pilots, that have been incorporated in the last open call (December 2020), should be added.

ROHub is a platform designed for and by researchers. It is very complete but it is difficult to use by citizens to access the information present in the platform. For this reason, we have decided to incorporate this information to the next versions of our data portal[12] (see *D4.3 Open Data Portal*). The new data portal not only will list the outputs of the project, but will also show the relations among them and allow users to navigate through them. Adopting the ROs to describe the outputs of the pilots, the data portal will become a *knowledge portal*.

The crafted research objects will continue to be deployed on ROHub and the data portal will use the provided API to visualize the elements within its interface.

[12] https://data.actionproject.eu/