United Nations
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inventors for the digital world

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The Software Heritage Acquisition Process

Software Heritage
THE GREAT LIBRARY OF SOURCE CODE

List of the authors

Short title	SWHAP
Full title	Software Heritage Acquisition Process
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Abstract

The source code of landmark legacy software is particularly important: it sheds insights in the history of the evolution of a technology that has changed the world, and tells a story of the humans that dedicated their lives to it.
Rescuing it is urgent, collecting and curating it is a complex task that requires significant human intervention.
This document presents the first version of SWHAP, the Software Heritage Acquisition Process: a protocol for the collection and preservation of software of historical and scientific relevance. SWHAP results from a fruitful collaboration of the University of Pisa with Software Heritage in this area of research, under the auspices of UNESCO, and has been validated on a selection of software source code produced in the Pisa area over the past 50 years.

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Contents

1) Introduction

Software is everywhere, binding our personal and social lives, embodying a vast part of the technological knowledge that powers our industry, supports modern research, mediates access to digital content and fuels innovation. In a word, a rapidly increasing part of our collective knowledge is embodied in, or depends on software artifacts.

Software does not come out of the blue: it is written by humans, in the form of software Source Code, a precious, unique form of knowledge that, besides being readily translated into machine-executable form, should also "be written for humans to read" (Abelson and Julie Sussman [1]), and "provides a view into the mind of the designer" (Shustek [6]).

As stated in the Paris Call on Software Source code as Heritage for sustainable development (Report [5]), from the UNESCO-Inria expert group meeting, it is essential to preserve this precious technical, scientific and cultural heritage over the long term.

Software Heritage is a non-profit, multi-stakeholder initiative, launched by Inria in partnership with UNESCO, that has taken over this challenge. Its stated mission is to collect, preserve, and make readily accessible all the software source code ever written, in the Software Heritage Archive. To this end, Software Heritage designed specific strategies to collect software according to its nature (Abramatic, Di Cosmo, and Zacchiroli [2]).

For software that is easily accessible online, and that can be copied without specific legal authorizations, the approach is based on automation. This way, as of September 2019, Software Heritage has already archived more than 6 billion unique source code files from over 90 million different origins, focusing in priority on popular software development platforms like GitHub and GitLab and rescuing software source code from legacy platforms, such as Google Code and Gitorious that once hosted more than 1.5 million projects.

For source code that is not easily accessible online, a different approach is needed. It is necessary to cope with the variety of physical media where the source code may be stored, the multiple copies and versions that may be available, the potential input of the authors that are still alive, and the existence of ancillary materials like documentation, articles, books, technical reports, email exchanges. Such an approach shall be based on a focused search, involving a significant amount of human intervention, as demonstrated by the pioneering works reconstructing the history of Unix (Spinellis [7]) and the source code of the Apollo Guidance Computer (Burkey [4]).

This document presents the first version of SWHAP, the ***SoftWare Heritage Acquisition Process*** to rescue, curate and illustrate landmark legacy software source code, a joint initiative of Software Heritage and the University of Pisa, in collaboration with UNESCO.

Section 2 provides an *abstract* view of SWHAP, its steps, documents and resources. No specific assumptions on the *tools, platforms and technologies* that may be used to enact it are made, but some requirements are made explicit. Section 3 describes how the abstract process is implemented at the University of Pisa by leveraging the Git toolset and the GitHub collaborative development platform. This implementation is named SWHAPPE (SWH Acquisition Process Pisa Enactor) in this document. Finally, Section 4 provides a walkthrough on an annotated example, using a real world medium-sized software project (Attardi and Flagella [3]).

2) The process, abstract view

This section describes SWHAP, the acquisition process for software artifacts at an *abstract* level, that is, without making specific assumptions on the *tools, platforms and technologies* that may be used to perform the various operations described here.

2.1) Phases

The activities involved in the acquisition process can be organized in the following four phases, of which the first one is *conservative*, i.e., it is devoted to save the raw materials that the other phases will build upon.

Figure 1 provides a pictorial view of the process, its phases, data stores and roles.

Collect

The purpose of this phase is *to find* the source code and related materials and *gather* it *as is* in a physical and/or logical place where it can be properly *archived* for later processing.

Various *strategies* are possible for collecting the raw materials: a dedicated team may proactively search for the artifact of specific software that has been identified as relevant (*pull approach*), or a crowdsourcing process may be set up to allow interested parties to submit software that has not been previously identified (*push approach*).

Source code can be provided in a *digital* or *physical* form. Typically, source code for old machines (such as the first Italian computer, CEP, now exposed in the Pisa museum of computing) is available only as paper printouts that may even include hand-written comments: all these materials deserve to be preserved.

Related materials can include research articles, pictures, drawings, user manuals: all of these are part of the software history and need to be preserved as well as the source code.

At this stage of elaboration of the process, this phase is better thought of as *abstract*, in the sense that several, more focussed descriptions should be provided to cater for the different situations identified. The same applies to the Curator role, which may need different capabilities in different scenarios.

Curate

The purpose of this phase is *to analyze, cleanup and structure* the raw materials that have been collected.

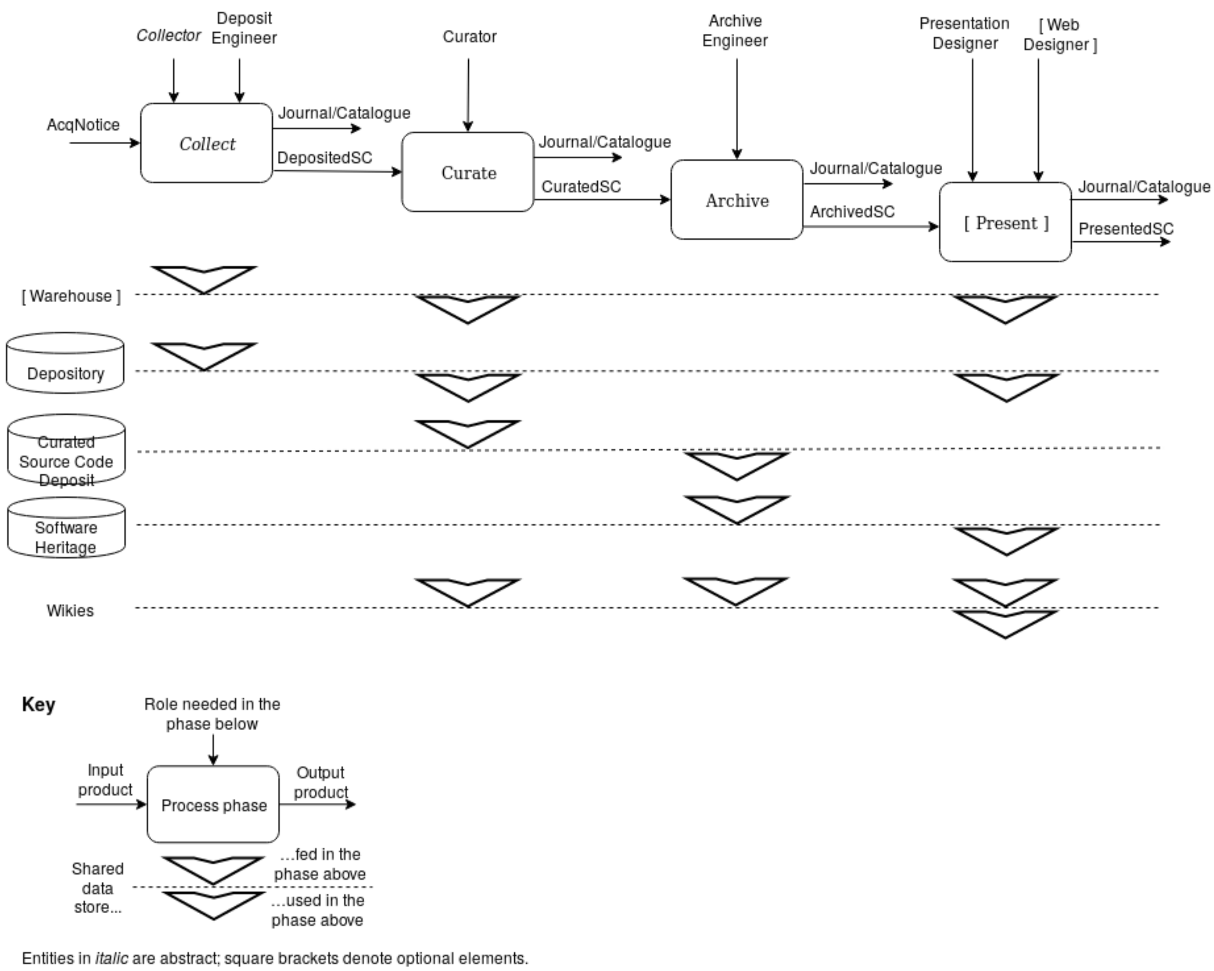


Figure 1: Source code acquisition process.

Preparing software source code for archival in **Software Heritage** requires special care: the source code needs to be *cleaned up*, different *versions* with their *production dates need to be ascertained*, and the *contributors need to be identified* in order to build a *faithful history of the evolution* of the software over time.

Also, proper *metadata* should be created and made available alongside the source code, providing all the key information about the software that is discovered during the curation phase. We recommend to use the vocabulary provided by **CodeMeta** as an extension to schema.org (see https://codemeta.github.io/terms/); this includes the software runtime platform, programming languages, authors, license, etc.

Particular care is required to *identify the owners* of the different artifacts, and *obtain if needed the necessary authorizations* to make these artifacts publicly available[1].

Archive

The purpose of this phase is to contribute the curated materials to the infrastructures specialized for each kind of materials: ***Software Heritage*** for the *source code*, ***Wikimedia*** for *images or videos*, ***open access repositories*** for *research articles*, ***Wikidata*** for *software descriptions and properties*, and so on.

Well established guidelines are available for contributing materials to Wikimedia (see https://commons.wikimedia.org/wiki/Co and Wikidata (see https://www.wikidata.org/wiki/Wikidata:Data_donation), hence we will focus primarily on curating and contributing the software source code to Software Heritage, a process that is new and may require rather technical steps.

Present

The purpose of this phase is to create dedicated presentations of the curated materials.

Once the curated materials are made available in the dedicated infrastructures, it is possible to use it to create presentations for a variety of purposes: special events, virtual or physical expositions for museums or websites.

For this, the archived materials need to be referenced using the identifiers that each platform provides for its contents. Software Heritage provides intrinsic persistent identifiers that are fully documented at https://docs.softwareheritage.org/devel/swh-model/persistent-identifiers.html

The presentation phase is out of the scope of this document, and as such we are currently not providing a supporting implementation. Anyway, a good example of what can be done is the https://sciencestories.io website.

2.2) An iterative process

New information may arise at any time: new raw materials may be discovered, refined information may be identified that needs to be added to the curation, and mistakes may need to be corrected. Hence, the overall process must be seen as *iterative*, in the sense that, when new data are available, the pertinent phase can be re-entered and the process enacted once more from there to update all the relevant information. This suggests that, whenever possible, the data stores should be fully versionable, not to loose historical information about the acquisition process itself.

[1] This is a complex issue, that may need to be handled according to country-specific regulations and is out of the scope of the present document. In the United States, one may leverage the "fair use" doctrine, see for example the detailed analysis presented in https://www.softwarepreservationnetwork.org/bp-fair-use/

2.3) Resources needed by the process

As any process supported digitally, SWHAP needs both human and technical resources to be enacted.

First of all, several data stores and working areas are needed, to save and make public the intermediate products, which are themselves of value, as already mentioned, and to pass the collected information across the phases. These are shown in the lower part of Figure 1, and are summarized here.

Warehouse

A physical location where physical raw materials are safely archived and stored, with the usual acquisition process[2].

Depository

A virtual space where digital raw materials are safely archived. The raw digital materials found in the Depository are used in the Curation phase to produce the source code that Software Heritage can ingest in the Archive phase.

The Depository holds also the related raw materials that may be elaborated and deposited in locations like WikiData, WikiMedia etc. - referred to as **Wikies** in fig. 1 - in the other phases.

Workbench

Any implementation of the process will need a virtual space and working environment where the activities can be carried out, with support for temporary storage and for logging the various operations in a journal.

Curated source code deposit

A fully versioned repository, holding the reconstructed development history of the source code, in view of its transfer to Software Heritage.

Catalogues and journals

As shown in fig. 1, according to the best practices of the archival sciences, each phase shall produce both a *Catalogue* of its products and a *Journal* recording its activities - *who did what, and when.* A list of the *Actors* involved in the process is also necessary. Provision to store all these information safely has to be foreseen in any supporting implementation.

2.4) Roles in the process

With respect to the human resources, several roles are needed to enact the process, as indicated in the top part of fig. 1. Here is a short summary of the involved capabilities.

Collector

Searches and receives the raw materials. Identifies, classifies and separates source code and ancillary materials.

[2] See for example https://collectionstrust.org.uk/spectrum/.

Deposit engineer

Masters the procedures to archive physical and digital materials, in the local context.

Curator

Prepares the version history, identifying the authors and other contributors. Provides a context to the source code, choosing among the ancillary materials.

Archive engineer

Masters the procedures to transfer the curated source code to SWH and to publish the context in the Wikies.

Presentation designer and Web engineer

These are out of the scope of this document, and are mentioned only to note that, though most of the presentations of the archived software will be on line, the abilities to design the contents of a presentation should be considered separately from the technical ones.

Remark the technical resources described above in abstract terms, may be implemented in a variety of ways. For example, one can imagine a single Depository for all the software projects that are collected, but it is also possible to use a separate Depository for each software project, and the same holds for all the other areas.

Remark the roles indicated above need not necessarily be played by different persons, e.g., Collector and Curator may be the same person, nor be played by a unique person, e.g., there can be several cooperating Curators, in case of large systems.

2.5) Implementation requirements

The abstract process may be implemented using different tools, platforms and technologies, as long as the following key requirements are satisfied.

Long term availability

The places where the artefact (both raw and curated) are stored must provide sufficient guarantees of availability over the long term. These places may be physical (warehouses), or logical (depositories).

Historical accuracy

Any supporting implementation should support the faithful recording of the authorship of the source code as well as of the reconstruction process, e.g., via a flexible versioning system.

Traceability

It must be possible to trace the origin of each of the artifacts that are collected, curated and deposited. For physical materials, we refer to common practice[3]. For digital artifacts, it is recommended to keep a *journal of all the operations* that are performed, and to automate them as much as possible, as the

[3]See for example in https://collectionstrust.org.uk/spectrum/.

collection and curation process may require several iterations.

Openness

Any supporting implementation should be based on open and free tools and standards.

Interoperability

Any supporting implementation should provide support for the cooperation and coordination of the many actors playing the many roles of the acquisition process.

3) The process, a concrete view

In order to implement SWHAP, the first step is to decide how to instantiate the needed storage and working areas: Warehouse, Depository, Curated source code deposit and Workbench.

The Warehouse is quite similar to the usual storage area where museums preserve their collections; it will need to be set up in a specific physical location, following the well established process for museums, so we will not cover it in this guide.

The other areas, which are virtual spaces, can very well be set up using distinct digital platforms, but it is also possible to instantiate all of them on a single platform.

This choice was made for the SWHAP Pisa Enactor (SWHAPPE), the implementation adopted by the SWHAP@Pisa project: SWHAPPE exploits the collaborative platform GitHub (https://github.com/) as a host platform for all the virtual support areas of the process.

The solutions adopted in SWHAPPE are described in detail in this section, together with their rationale.

3.1) General Motivation for using Git and GitHub

The choice of Git as the designated tool for traceability and historical accuracy, and of GitHub as the unifying platform to support the SWHAP process proceeds from several considerations that we review below.

First of all we discuss the choice of *Git*. One of the key requirements set forth for SWHAP is the need to ensure *full traceability* of the operations performed on the recovered digital assets. This means that each of the virtual places must provide means to record the history of the modifications made to the digital assets, with information on *who did what and when*. It is very convenient to use the same tool in all of the virtual places of the process, as this reduces the learning effort and streamlines the process. All modern version control systems provide the needed functionality, and we have chosen *Git* as our standard tool, as it is open source (another of our requirements) and broadly adopted. *Git* is a powerful tool, and requires some expertise to make the most out of it. However, a large part of the process is scriptable, and this will hide the underlying complexity to the final user, which can then focus on the main issue: curating and preserving the code and its history.

Another important motivation for our choice of Git is the ability to support *historical accuracy*, i.e., providing a faithful view of the history of both the recovered source code and the acquisition process, as prescribed by the SWHAP key requirements. This is properly accommodated by the commit and versioning mechanisms offered by Git, that allow to separate authors from committers: this way on can record both the story of the original software and the story of its curation.

Finally, we had to choose one of the many online platforms that allow to collaborate using *Git*. GitHub, GitLab.com and Bitbucket are the most known ones and are all regularly archived in Software Heritage, so that *long term availability* of their contents is preserved, no matter which one of these platforms is chosen.

Among all these platforms, GitHub is by far the most popular and active, and is also the platform adopted by the University of Pisa, so it was a natural choice, and we believe this will make the learning curve gentler for most SWHAP adopters.

In the following, we provide detailed guidelines to instantiate the process using Git on GitHub. We think that most of what is described in the guide can be easily adapted to any of the other *Git*-based collaborative platforms.

3.2) SWHAP - GitHub correspondence

SWHAPPE is a straightforward implementation of the abstract process, which concretizes the (logical) areas described above by means of *repositories* in GitHub: there are three repositories for each source code acquisition, one for each area of the abstract process:

Workbench repository, to implement the Workbench, i.e. a working area where one can temporarily collect the materials and then proceed to curate the code;

Depository repository, to implement the Depository, where we can collect and keep separated the raw materials from the curated source code;

Source Code repository, to implement the Curated source code deposit, where we store the version history of the code; this version history is usually "synthetic", rebuilt by the curation team, for old projects that did not use a version control system.

Let's remark that SWHAPPE has *different* Workbench and Depository repositories for each code acquisition, but it would also be possible to use a single Workbench repository and/or a single Depository repository to work on all the collected software, provided one maintains a well-organised directory structure which keeps the codes separated. On the other hand, we *need* a Source Code repository for each software project, to be actually ingested in the Software Heritage archive.

3.3) Process overview

GitHub features *template* repositories that can be instantiated whenever needed (see

https://help.github.com/en/articles/creating-a-template-repository). We used this feature in SWHAPPE, and designed a repository, SWHAP-TEMPLATE, that embodies the core support to enact the process. Its structure and use is shown in figure 2. In the picture and in the following *SWName* is a variable that takes the name of the acquired code as its value at each instantiation.

Once SWHAP-TEMPLATE has been instantiated, the *SWName-Workbench* repository so created need to be cloned to the user's machine, so that he can work on the collected files locally - the Git clone mechanism ensures that these changes can be safely moved to the original repository, for publication and sharing with other actors in the acquisition.

We create two dedicated *branches*[4], that allow to track separately the operations that will be later moved to the Depository and the Development History Deposit: *Depository*, to contain the raw materials and the browsable sources as well as the metadata, and *SourceCode* to organize the source code in view of the reconstruction of its development history. Finally, the *Depository* and *SourceCode* branches become two repositories: the latter is shipped to the Software Heritage archive, the former is published by the organization promoting the acquisition.

Figure 2. Overview of the SWHAPPE process.

3.4) The SWHAP template

The structure of the template is shown in Fig. 3.

First of all, we can see a correspondence between the Depository presented in the process and the area provided by `raw_materials` and `browsable_source`: indeed, these two folders will be moved in order to instantiate the Depository, once they have been loaded, the former with the original materials, just as they

[4] More information on Git *branches* can be found in Appendix B.

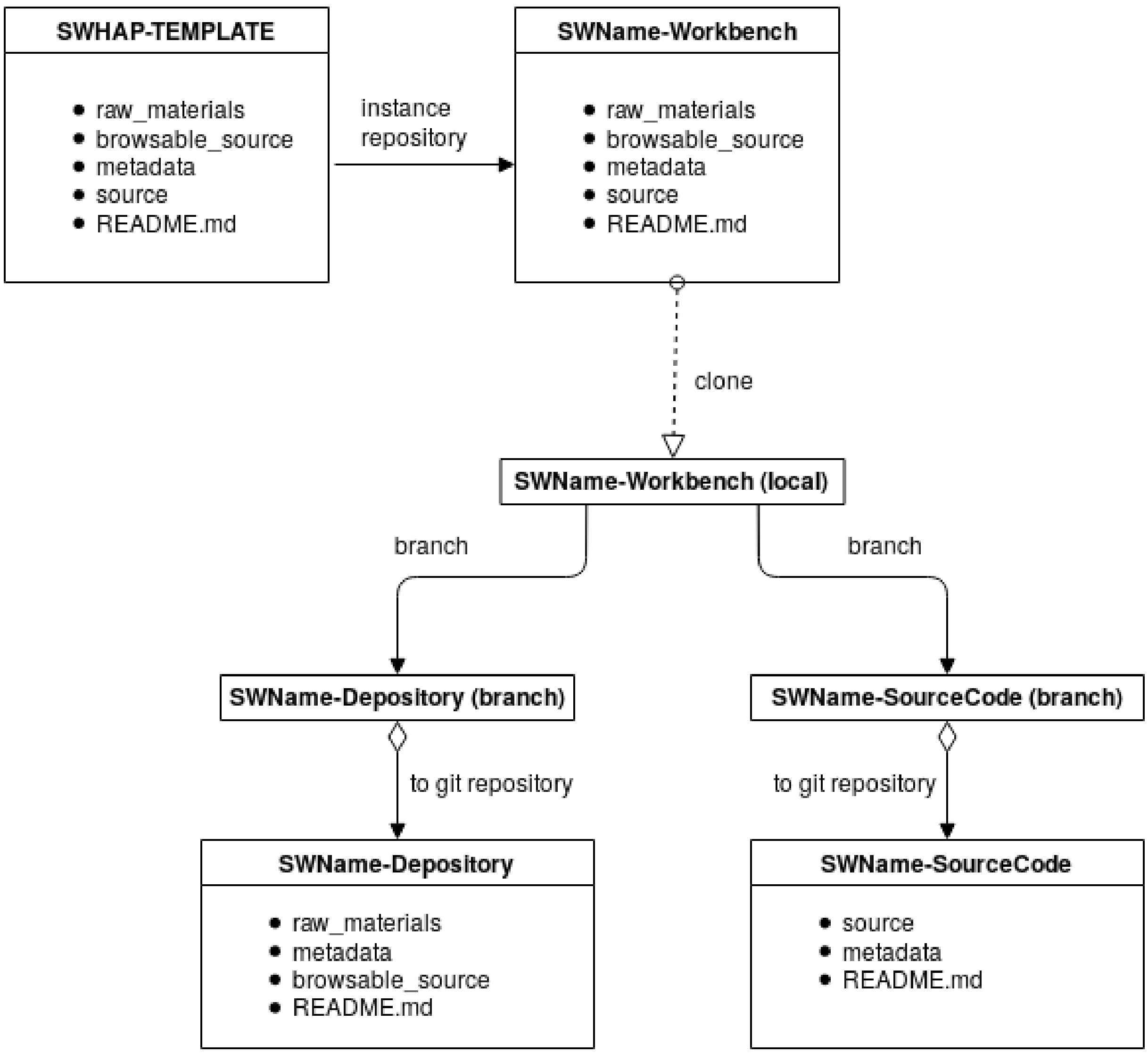


Figure 2: Overview of the SWHAPPE approach

have been found or submitted, the latter with a first revision of the source code, made accessible through the GitHub web interface, e.g., archives should be decompressed, code transcribed from pictures, etc.

The source folder is provided as the starting point for the creation of the Source Code *Git* repository, in the curation phase. The curator has to recognize each major version of the code, and refactor it accordingly - one separate folder per each version. To create the Source Code Deposit, however, we exploit the *commit* and *versioning* mechanisms of *Git*.

As for the metadata folder, here we record all the information about the software and the acquisition process (catalogue, actors, journal, etc.). The guidelines to fill this part are given in the template itself.

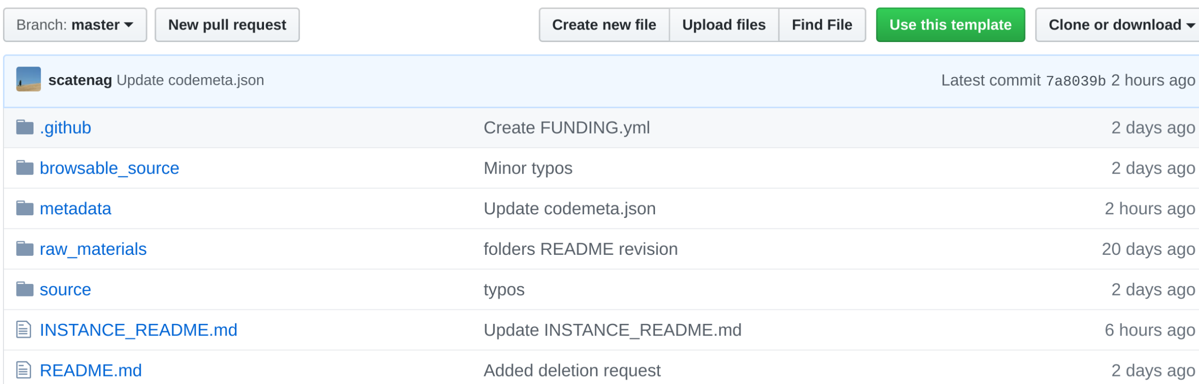


Figure 3: Top structure of the Template repository.

3.5) The process, step by step

Instantiation

The first step is to create an instance of the SWHAP-TEMPLATE[5], that should be named SWName-Workbench, and then to clone it to obtain a local copy on your machine[6].

From this point on, you'll be able to upload files and to modify/copy/move them locally, and use *Git* commands to push changes to GitHub.

Let us now see the steps to be followed, together with some explanations.

Collect phase

Upload files in raw_materials

All the collected files must be uploaded in the raw_materials folder.

If there are physical materials, folder raw_materials should contain a reference to the related Warehouse, that may follow the Spectrum guidelines [8].

Move the source code to browsable_source

All the source code files must then be put into the browsable_source folder.

[5] See the documentation on https://help.github.com/en/articles/creating-a-repository-from-a-template
[6] See the documentation on https://help.github.com/en/articles/cloning-a-repository

If the raw material is an archive, you should unpack it locally and then upload the result on GitHub by performing a push[7].

If the code was only available in non digital form (e.g. printed listings), you can either transcribe it manually, or use a scanner and an OCR (optical character recognition) tool to parse it. See Appendix A for a list of suggested tools.

Particular care should be used to ensure the files in browsable_source have the correct extension: scanner and OCR usually generate files with a generic .txt extension, that must be changed to the extension typically used for the programming language they contain.

Note that, at this stage, we are not interested in precise information about the versions of the software. The purpose is to have machine-readable documents.

Finally, in preparation for the curation phase, you may want to copy the files in browsable_source to the source folder.

Create Depository

The next step is to create the branch Depository, containing only the folders raw_materials and browsable_source, together with the metadata updated to this point. Then, create the Depository repository from this branch.

Curate phase

Curate the source code

Once the Depository creation is complete, you can move back to the source folder in the master branch. Here you have to divide and number the versions, putting the files of each one in a dedicated folder and determining who did what and when.

In practice, this means that *for each version of the software* you need to ascertain:

- the *main contributing author*,
- the *exact date* of the release of this particular version

This information should be consigned in a dedicated metadata file, version_history.csv, with the following fields:

Field name	description
directory name	name of the directory containing the source code of this version
author name	name of the main author
author email	email of the main author, when available
date original	original date when this version was made
curator name	name of the curator person or team
curator email	the reference email of the acquisition process
release tag	a tag name if the directory contains a release, empty otherwise
commit message	text containing a brief note from the curation team

(Re-)Create the Development History

Now we are ready to (re-)create the development history of the software. First you need to create a branch Source Code, with the *src* folder.

[7] See the documentation on https://help.GitHub.com/en/articles/adding-a-file-to-a-repository-using-the-command-line.

Then, you can proceed in two ways:

- *manually*: using the *Git* commands to push the successive versions into the source folder, reading the information collected in the file `version_history.csv` to set the fields for each version to the values determined during the curation phase;
- *automatically*: using a tool that reads the information from `version_history.csv` and produces the synthetic history in a single run; one such tool has been developed, DT2SG (https://github.com/Unipisa/DT2SG) , and you can see a running example in the next section.

The result will be a branch that materializes the development history of the software via Git commits and releases.

Create the final repository

Finally you can create the "official" software repository, taking the versions history from the src branch and the metadata from the master branch.

3.6) Iteration

New material may be discovered after the process has been completed, triggering an iteration of some of the phases described above. In this case, we recommend to proceed as follows:

- if new raw material (non-source code) is found, we have to clone the Depository repository and add new items to it. In this way, the performed commits will correctly follow the previous ones.
- if new source code is found, after we collected it in the Depository, we have the following cases:

  (1) The recovered source code is related to a version which is already included in the software history.

  (2) The source code represents a completely new version, with respect to the software history as it was previously collected.

We are not finished yet, since in both cases the SourceCode repository is no longer consistent with the collected source code, and we have to recreate it, performing the following steps:

- Delete the SourceCode repository.
- Move back to the Workbench and according to the current case:

  if (1), add the source code to the correct version.

  if (2), add the new version folder with the related metadata.
- Recreate the software history as for the first iteration.

4) A walkthrough on a running example

In this section we will show the process at work on one of the first source code acquired by the SWHAP@Pisa project, the CMM conservative garbage collector for C++ that was initially developed for project PoSSo (Polynomial System Solver) and later became the basis for the Java GC and the Oak GC [7]. Since it has evolved through various versions, CMM is a good workbench for SWHAPPE and an appropriate example to show how to use the tools.

Starting the process

The acquisition process of the CMM software started informally when one of the authors, still active in the Computer Science department, learned about the SWHAP project, and proposed to search for the source code and make it available to the project. Shortly after, we received a mail message with all the sources, as well as the associated research article. Since the materials were already in digital form, the process does not involve a Warehouse.

Instantiation

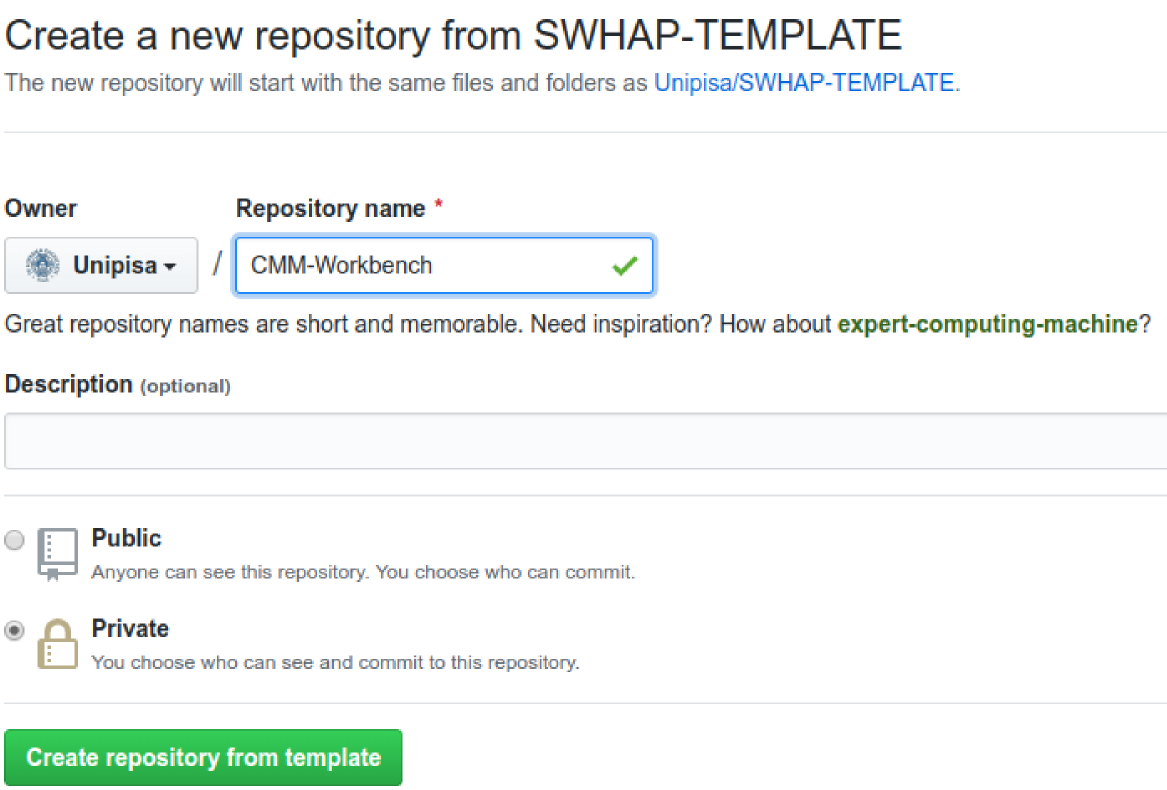


Figure 4: Instantiation of the template

We instantiate on GitHub the SWHAP repository template[8] into a new repository[9], that we name "CMM-Workbench". This action, as most of the following ones, can be performed through the user interface (as shown in Figure 4), or programmatically through the GitHub API.

It has the same directory structure as SWHAP-Template, as shown in Figure 3.

To facilitate the search of the created repository, we add the "software-heritage", "workbench" and "swhappe" tags, as shown in Figure 6.

To start working, we create a local copy on our computer, cloning this repository[10]. By clicking on the green button "clone or download" (Figure 5), we get a link that we can use for this purpose in the following command from the command line:

```
git clone https://github.com/Unipisa/CMM-Workbench.git
```

Now, we have a local copy of the CMM-Workbench, and we can, first of all, update the README.md file with the correct name and description of the acquisition, and synchronize it with the remote repository:

```
git add README.md
git commit README.md -m "Updated README"
git push
```

We are now ready to start the collect phase.

Upload files in raw_materials

Here we fill the local folders with the collected material. In the case of CMM, we got a tar.gz file containing the various versions of the software, organized according to an ad-hoc versioning system. In the raw_materials folder we store also the paper presenting the software and the email that Giuseppe Attardi sent us along with them, and we commit all these new contents:

```
git add raw_materials
git commit -m "Added raw material"
git push
```

The resulting state of raw_materials is shown in Figure 7.

Unpack the source code in the browsable_source directory

In order to get a browsable version of the source code, we decompress the .tar.gz archive into the browsable_source folder

```
tar -xzf raw_material/cmm.tgz -C browsable_source
```

and commit the changes as done for the raw_materials folder

```
git add browsable_source
git commit -m "Added browsable source"
git push
```

[8] https://github.com/Unipisa/SWHAP-TEMPLATE

[9] The repository can be either public or private according to the policy of the acquisition team.

[10] See Appendix B for a brief discussion on the convenience of working locally, rather than remotely via the web interface.

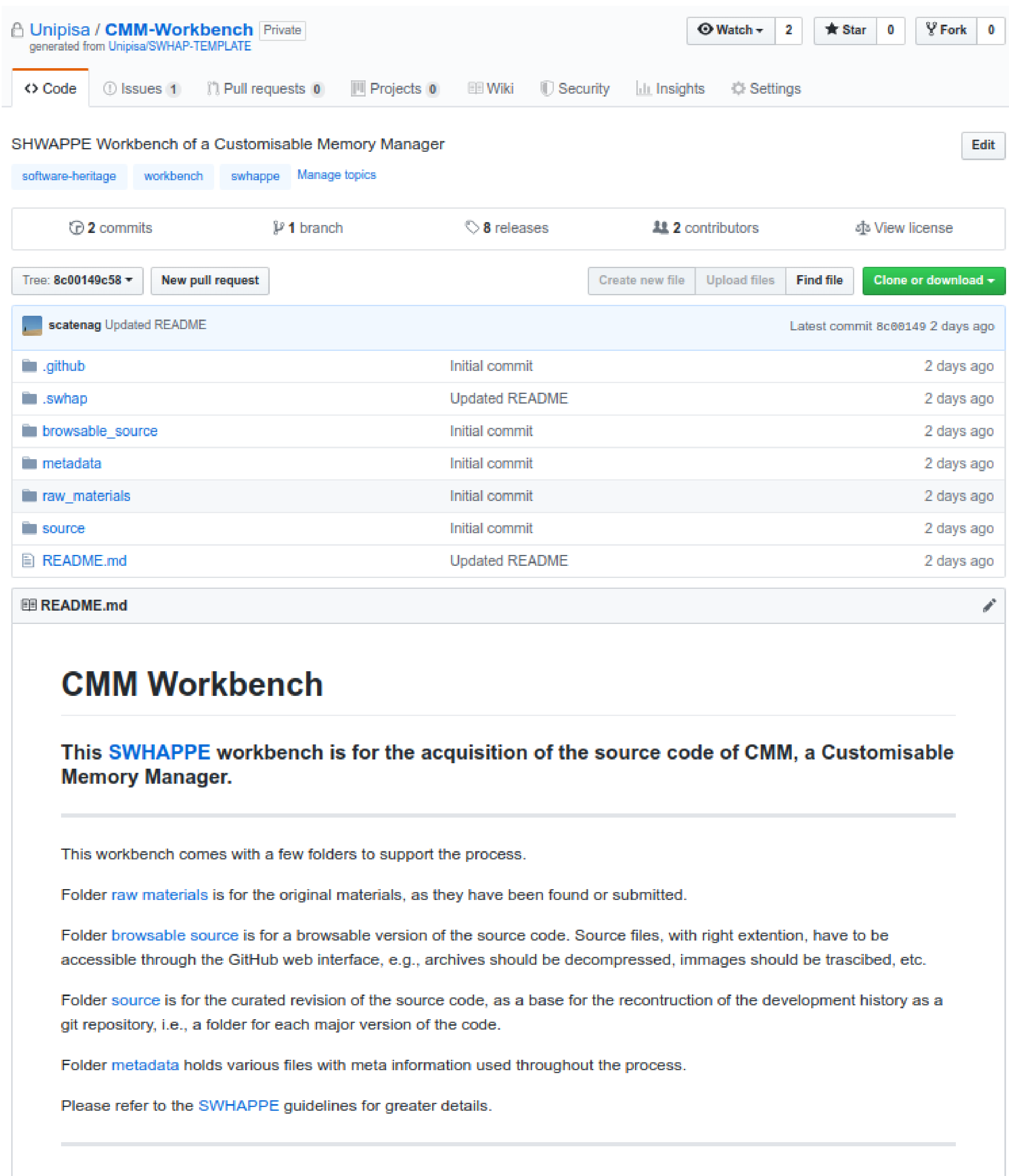


Figure 5: Instantiated workbench for CMM.

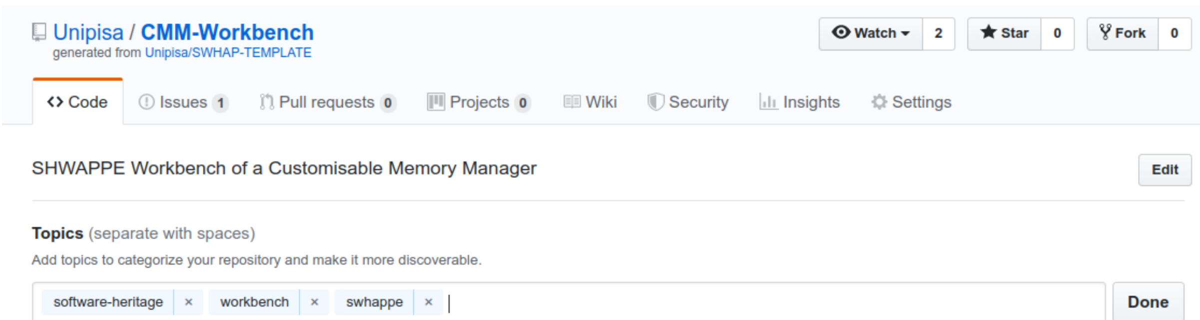


Figure 6: Tags for the workbench for CMM.

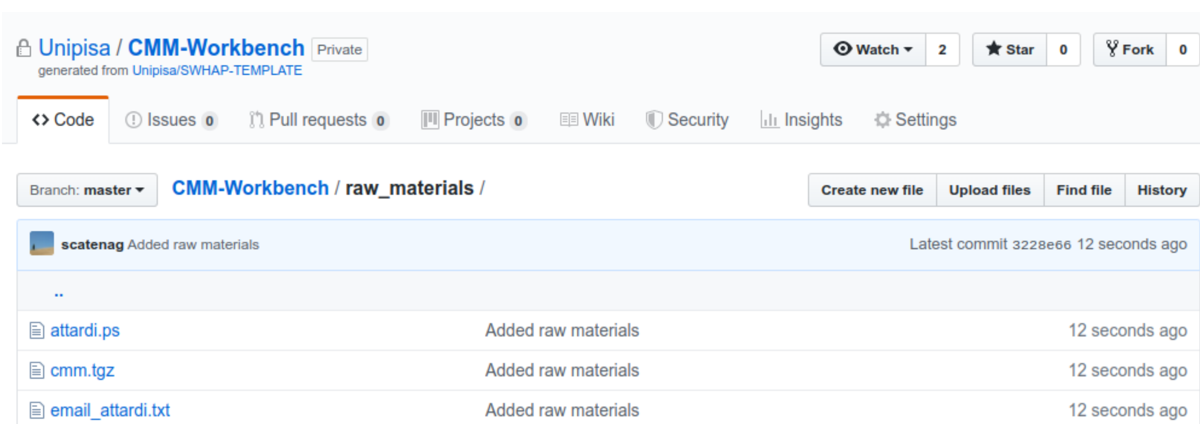


Figure 7: CMM raw materials on GitHub.

We can see the resulting state of the repository in Figure 8.

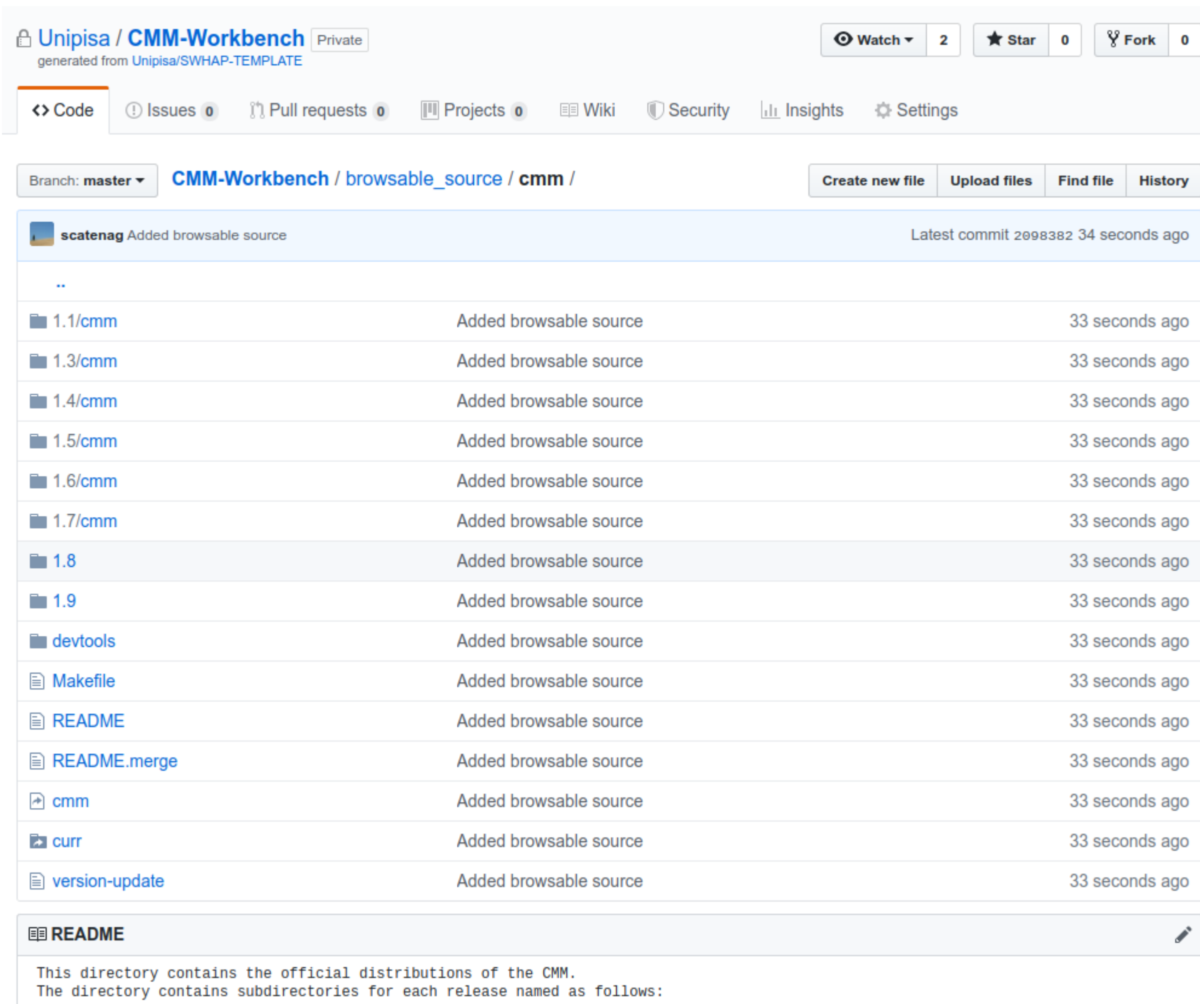


Figure 8: CMM browsable sources on GitHub.

Finally, in preparation for the next phase, curation, we copy the files contained in browsable_source into the source folder[11].

```
cp -r browsable_source source
```

Again, we stage changes as in the previous two steps.

```
git add source
git commit -m "Added source"
git push
```

[11] Here shown with unix command line.

Create Depository

The Depository has been filled, hence we create the Depository as an orphan branch, i.e., with no references to the parent repository, using the checkout command:

```
git checkout --orphan Depository
```

As a result, we moved to the Depository branch. Here we modify the README (guidelines to fill the README file are given in the template) and remove the `source` and `metadata` folder, since they are not interesting for this area:

```
git rm -rf source metadata
```

We stage the last modifications and then push to the remote repository.

```
git add .
git commit -m "Added raw materials from master branch"
git push --mirror origin
```

We are almost ready to move the Depository to a new repository: before that, however, we have to create the new remote repository on GitHub (Figure 9 shows how to do this using the web interface; here too one could use the GitHub API instead).

To facilitate the search of the created repository, we add the "software-heritage", "depository" and "swhappe" tags (in the same way of what done for the workbench as shown in Figure 6).

Final depository

Finally, we can perform a push and fill the remote repository.

```
git push https://github.com/Unipisa/CMM-Depository.git +Depository:master
```

We can check the resulting repositories via the web interface (Figure 10): CMM-Depository is now filled with the pushed materials.

The Depository branch is then removed from the Workbench, to avoid having multiple copies that may diverge. Should new materials became available, a new iteration of the process should start, re-initializing the Workbench with the information in the Depository.

```
git checkout master
git push --delete origin Depository
git branch -D Depository
```

Curate the code

Version History In this phase, the curation team should clean up the code and organize it in separate folders, one per version. In the case of CMM, the code is already structured this way, as shown in Figure 10, so there is nothing to do.

In order to support the (re-)creation of the development history of the original project, we prepare the `version_history.csv` file with the appropriate metadata (see Figure 11).

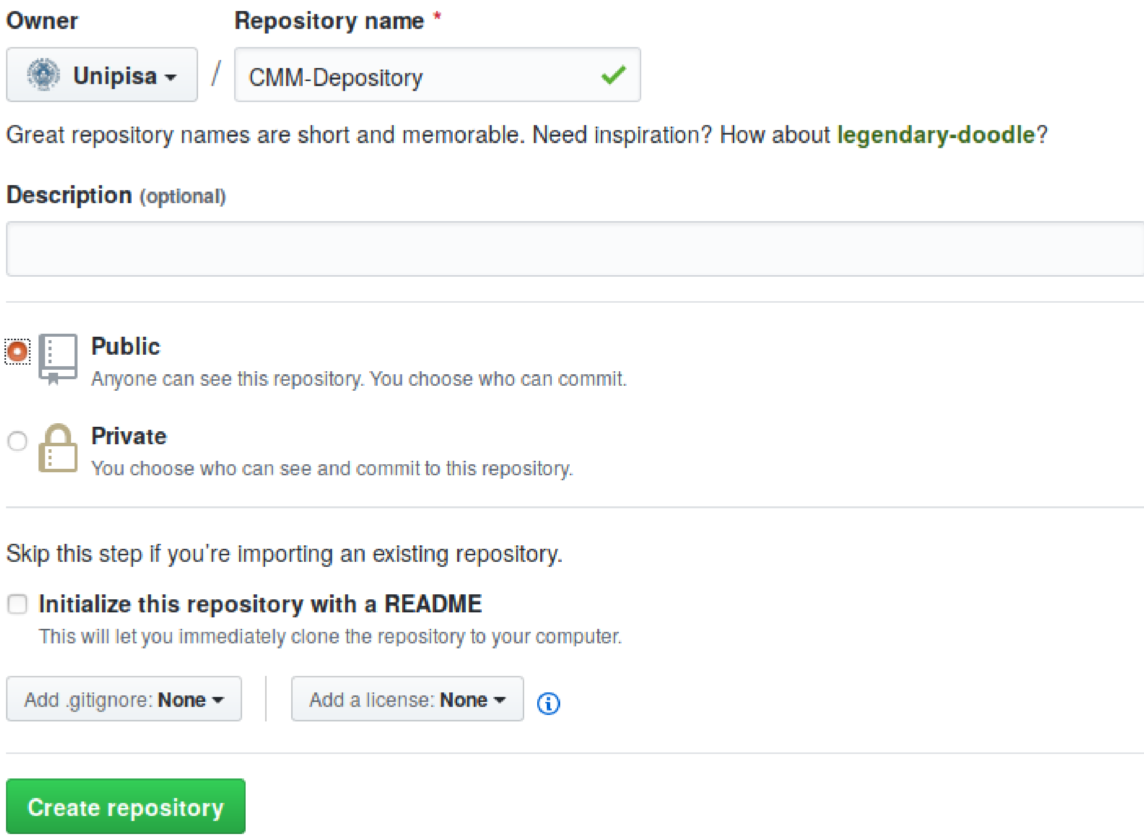


Figure 9: CMM-Depository creation.

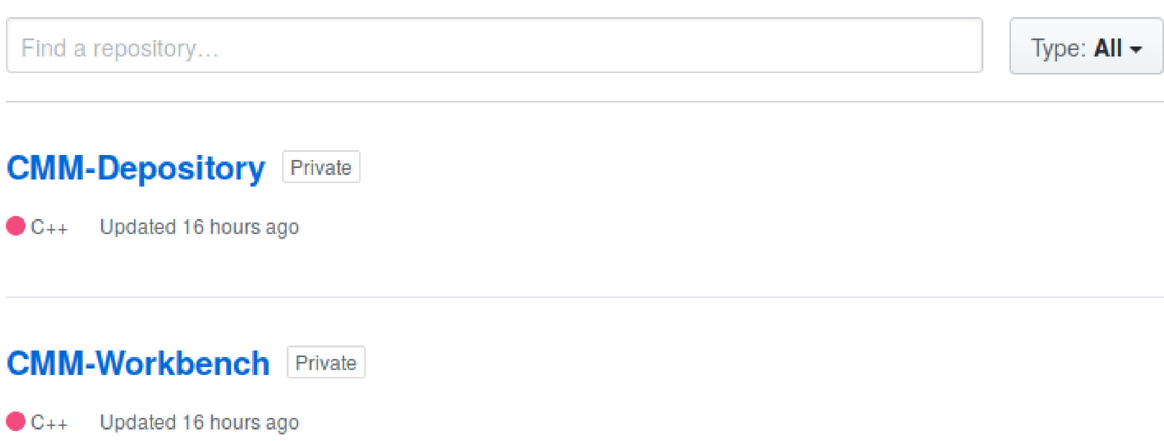
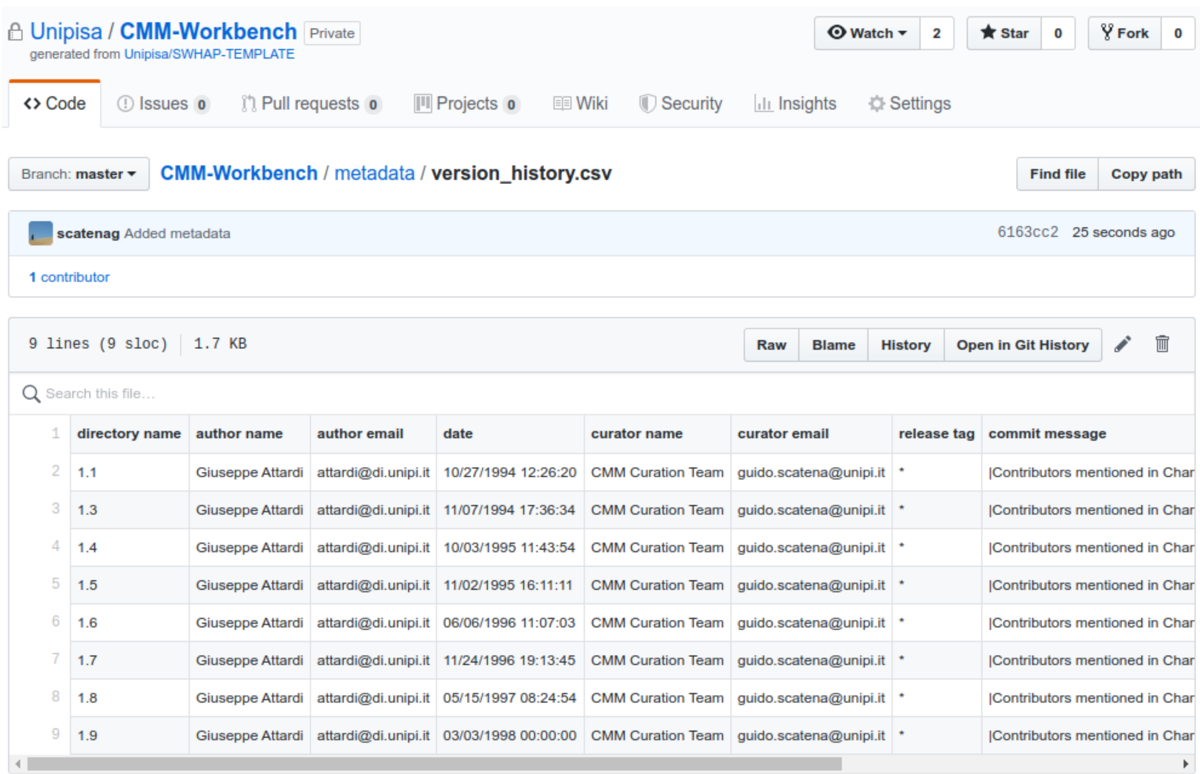


Figure 10: The CMM repositories at the end of the collect phase.



directory name	author name	author email	date	curator name	curator email	release tag	commit message
1.1	Giuseppe Attardi	attardi@di.unipi.it	10/27/1994 12:26:20	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.3	Giuseppe Attardi	attardi@di.unipi.it	11/07/1994 17:36:34	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.4	Giuseppe Attardi	attardi@di.unipi.it	10/03/1995 11:43:54	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.5	Giuseppe Attardi	attardi@di.unipi.it	11/02/1995 16:11:11	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.6	Giuseppe Attardi	attardi@di.unipi.it	06/06/1996 11:07:03	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.7	Giuseppe Attardi	attardi@di.unipi.it	11/24/1996 19:13:45	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.8	Giuseppe Attardi	attardi@di.unipi.it	05/15/1997 08:24:54	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char
1.9	Giuseppe Attardi	attardi@di.unipi.it	03/03/1998 00:00:00	CMM Curation Team	guido.scatena@unipi.it	*	|Contributors mentioned in Char

Figure 11: The version history for CMM

Codemeta Contextually we fill the metadata/codemeta.json template file (see Figure 12, left) with metadata according to CodeMeta guidelines obtaining what shown in (see Figure 12, right).

```
{
   "@context": "https://doi.org/10.5063/schema/codemeta-2.0",
   "@type": "SoftwareSourceCode",
   "identifier": "a unique identifier",
   "description": "a brief description of the software",
   "applicationCategory": "Type of software application, e.g. 'Game, Multimedia'",
   "name": "software name",
   "codeRepository": "URL to related resources",
   "license": "info about the license",
   "version": "X.X",
   "keywords": [
      "tag for the software",
      "other tag"
   ],
   "releaseNotes": "release notes and comments",
   "funding": "software funded by...(e.g. specific grant)",
   "runtimePlatform": "operating system",
   "softwareRequirements": [
      "dependencies and other requirements"
   ],
   "developmentStatus": "from https://www.repostatus.org/ e.g. Unsupported",
   "dateCreated": "YYYY-MM-DD",
   "datePublished": "YYYY-MM-DD",
   "relatedLink": [
      "https://..",
      "http://.."
   ],
   "programmingLanguage": "main programming language",
   "isPartOf": "maybe the software is part of some project",
   "referencePublication": [
      {
         "@type": "ScholarlyArticle",
         "idendifier": "https://doi.org/xx.xxxx/xxxx.xxxx.xxxx",
         "name": "title of publication"
      }
   ],
   "author": [
      {
         "@type": "Person",
         "givenName": "Given",
         "familyName": "Family",
         "affiliation": "affiliation at the time of development",
         "email": "given.family@org.com"
      }
   ],
   "contributor": [
      {
         "@type": "Person",
         "givenName": "Given",
         "familyName": "Family",
         "affiliation": "affiliation at the time of development",
         "email": "given.family@org.com"
      }
   ]
```

```
{
   "@context": "https://doi.org/10.5063/schema/codemeta-2.0",
   "@type": "SoftwareSourceCode",
   "identifier": "CMM",
   "description": "conservative garbage collector for C++ developed for PoSSo",
   "name": "Customizable Memory Management",
   "codeRepository": "https://github.com/Unipisa/CMM",
   "applicationCategory": "Memory Management",
   "version": "1.9",
   "keywords": [
      "Garbage Collector",
      "Memory Management"
   ],
   "runtimePlatform": "SunOS 4.x, Solaris 2.x, Linux 1.x, 2.x, AIX (RS6000)",
   "softwareRequirements": [
      "g++"
   ],
   "developmentStatus": "Unsupported",
   "dateCreated": "1994-08-27",
   "datePublished": "1995-08-26",
   "programmingLanguage": "c++",
   "isPartOf": "PoSSo (Polynomial System Solver)",
   "referencePublication": [
      {
         "@type": "ScholarlyArticle",
         "idendifier": "https://doi.org/10.1006/jsco.1996.0013",
         "name": "Memory Mangement in the PoSSo Solver"
      }
   ],
   "author": [
      {
         "@type": "Person",
         "givenName": "Giuseppe",
         "familyName": "Attardi",
         "affiliation": "Dipartimento di Informatica, Università di Pisa"
      },
      {
         "@type": "Person",
         "givenName": "Tito Flagella",
         "familyName": "Tito Flagella",
         "affiliation": "Dipartimento di Informatica, Università di Pisa"
      },
      {
         "@type": "Person",
         "givenName": "Pietro",
         "familyName": "Iglio",
         "affiliation": "Dipartimento di Informatica, Università di Pisa"
      }
   ],
   "contributor": [
      {
         "@type": "Person",
         "givenName": "Carlo",
         "familyName": "Traverso",
         "affiliation": "Dipartimento di Informatica, Università di Pisa"
      },
```

Figure 12: CMM instantiation (right) of codemeta.json template (left)

License To conclude the curation phase, we have to identify licensing information.

If we find a file specyfing the licence in the source code, we have to copy its content in the metadata /LICENCE file. Otherwise, in the case there is no licensing file in the source and we obtained license information in other finds, we fill metadata/LICENCE according to the SPDX standard.

(Re-)Create the development History

The development history can now be (re-)created either by issuing manually (i.e. for each version directory) the appropriate git commands, or by using a specialised tool.

Manually We have to create a clean dedicated SourceCode branch

```
git checkout --orphan SourceCode
git rm -rf *
```

Then, for every directory containing a version of the source code, in chronological order, we copy its contents from the master branch to the current branch, and commit it with the appropriate metadata.

For example, for the directory 1.9 of the CMM sources, here is how we copy the source contents into our branch:

```
git checkout master -- source/1.9
mv source/1.9/* .
rm -rf source
```

Then we use the following template to create manually an individual commit/release:

```
export GIT_COMMITTER_DATE="YYYY-MM-DD HH:MM:SS"
export GIT_COMMITTER_NAME="Commiter Name"
export GIT_COMMITTER_EMAIL="email@address"
export GIT_AUTHOR_DATE="YYYY-MM-DD HH:MM:SS"
export GIT_AUTHOR_NAME="Author Name"
export GIT_AUTHOR_EMAIL=<email@address>"
git add -A
git commit -m 'Commit Message Here'
```

We also need to add an annotated tag to this version. For version 1.9 of CMM, here is the command we used, you can adapt it to your needs:

```
git tag -a 1.9 -m "Version 1.9"
```

Finally, we clean up the directory before importing a new version

```
git rm -rf *
```

With DT2SG And here is an example using the DT2SG tool

```
dotnet ./DT2SG/DT2SG_app.dll
  -r SWHAP-EXAMPLE/CMM-Workbench
  /source/cmm/
  -m SWHAP-EXAMPLE/CMM-Workbench
  metadata/version_history.csv
```

As a result we will find in our local repository a new local branch containing the rebuilt version history, that is shown in Figure 13.

Create the final repository

We move back to the master branch using the checkout command, then remove `raw_materials`, `browsable_source` and `source` from it:

```
git rm -rf raw_materials browsable_source source
```

We now create the README.md file, add it and commit changes:

```
git add README.md
git commit -m "Final repository created"
```

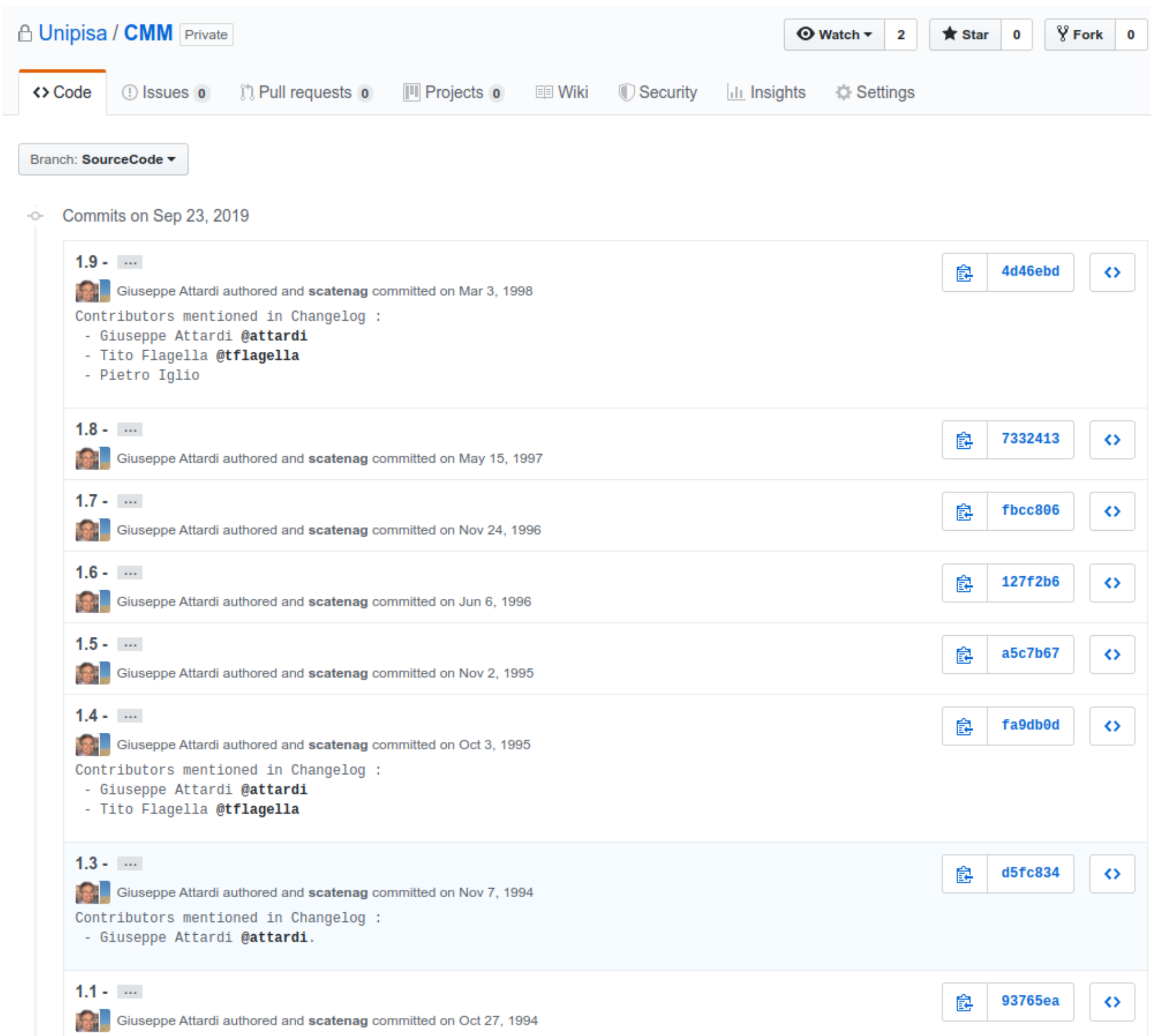


Figure 13: An excerpt of the synthetic history of CMM.

Now we create the final remote repository, that we call “CMM”, see Figure 14, and we push the relevant branches (and tags) to it.

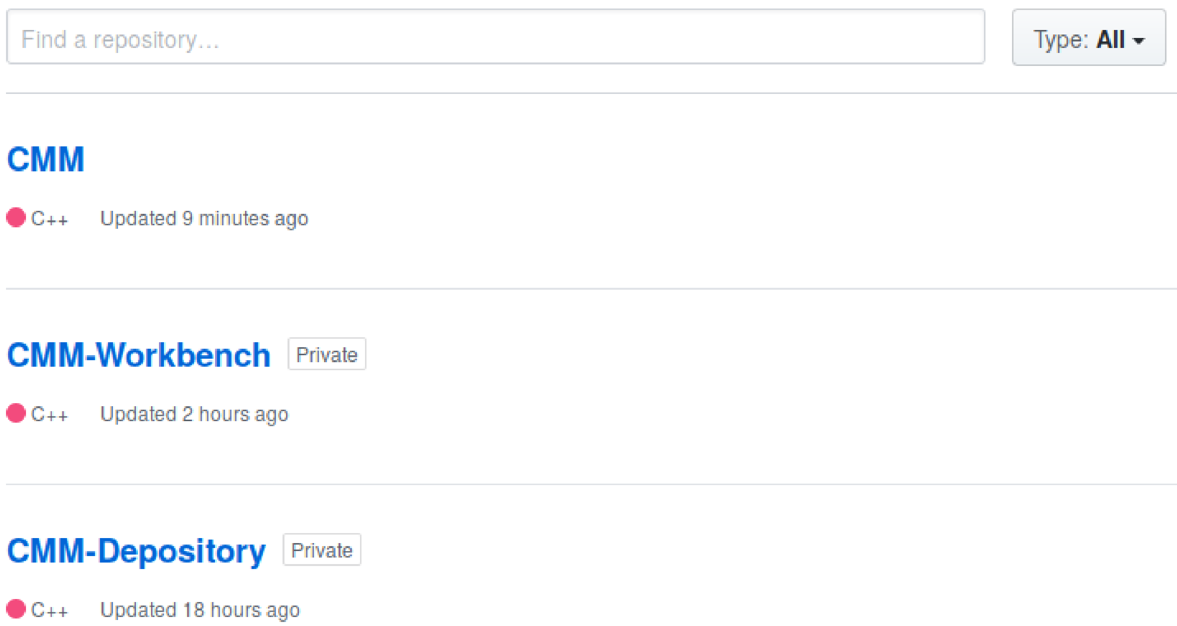


Figure 14: The creation of the final repository.

```
git push --tags git@github.com:Unipisa/CMM.git +master:master +SourceCode:SourceCode
```

To facilitate the search of the created repository, we add the “software-heritage”, “archive” and “swhappe” tags (in the same way of what done for the workbench as shown in Figure 6).

Figures 15, 16, 17 show the final result of CMM, their Depository and Workbench.

Publish the repositories and trigger Software Heritage acquisition

In order to publish the Depository and SourceCode repositories we have to set their visibility to “public”, either through GitHub web interface or using the GitHub API as follows:

```
curl -s -H 'Authorization: token '$auth_token''
 -H "application/vnd.github.baptiste-preview+json"
 --data '{"private": false}'
 -X PATCH https://api.github.com/repos/$org/$repository_archive
```

where **$repository_archive** is CMM or CMM-Depository and **$auth_token** is the authorizzarion token. As a result, the code is now publicly visible at

https://github.com/Unipisa/CMM/

Finally, we trigger the archival of this repository in Software Heritage, using the “save code now” functionality. This can be done using the web interface at **https://save.softwareheritage.org**, or by connecting to the API on the command line as follows:

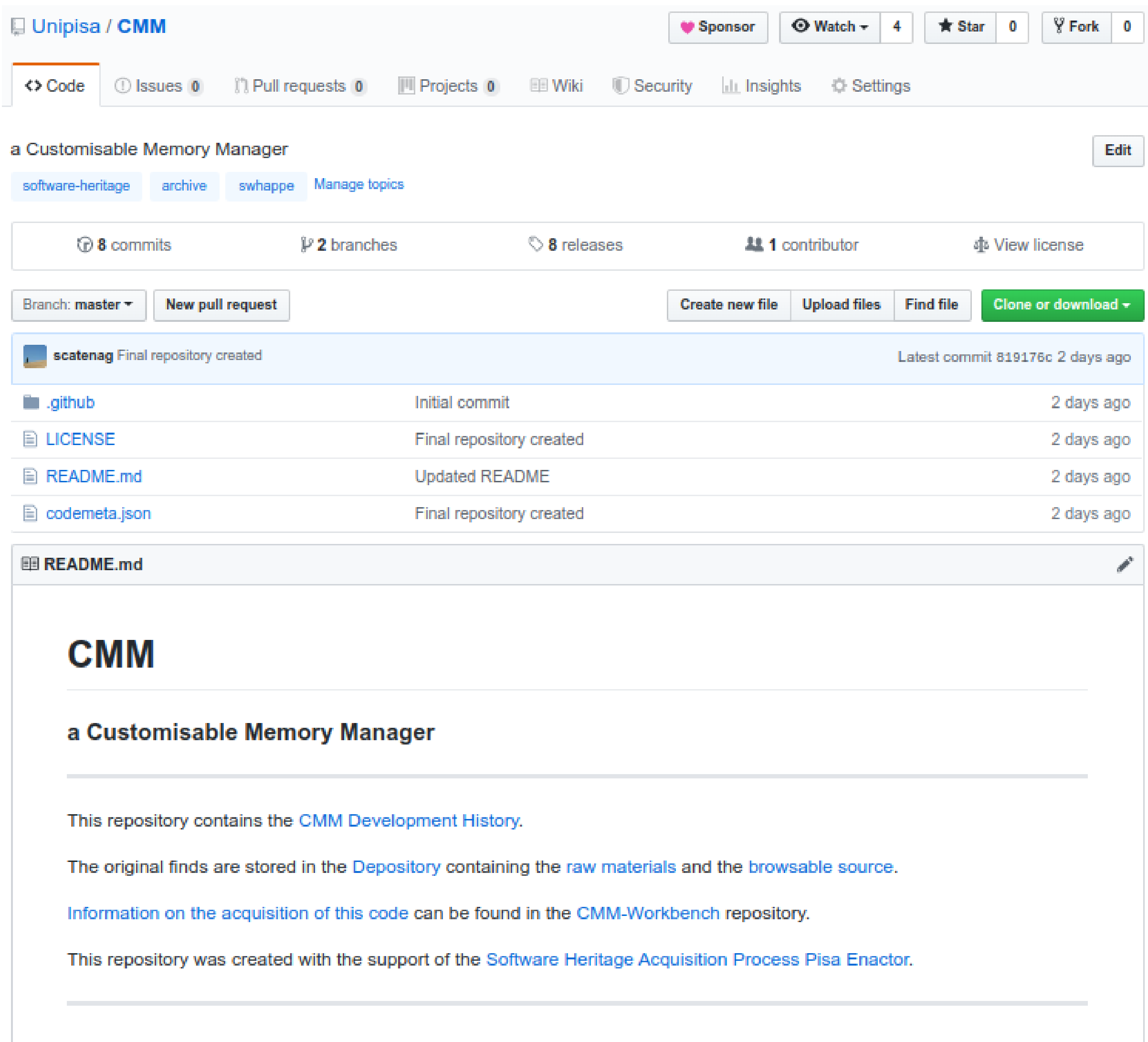


Figure 15: The final CMM repository.

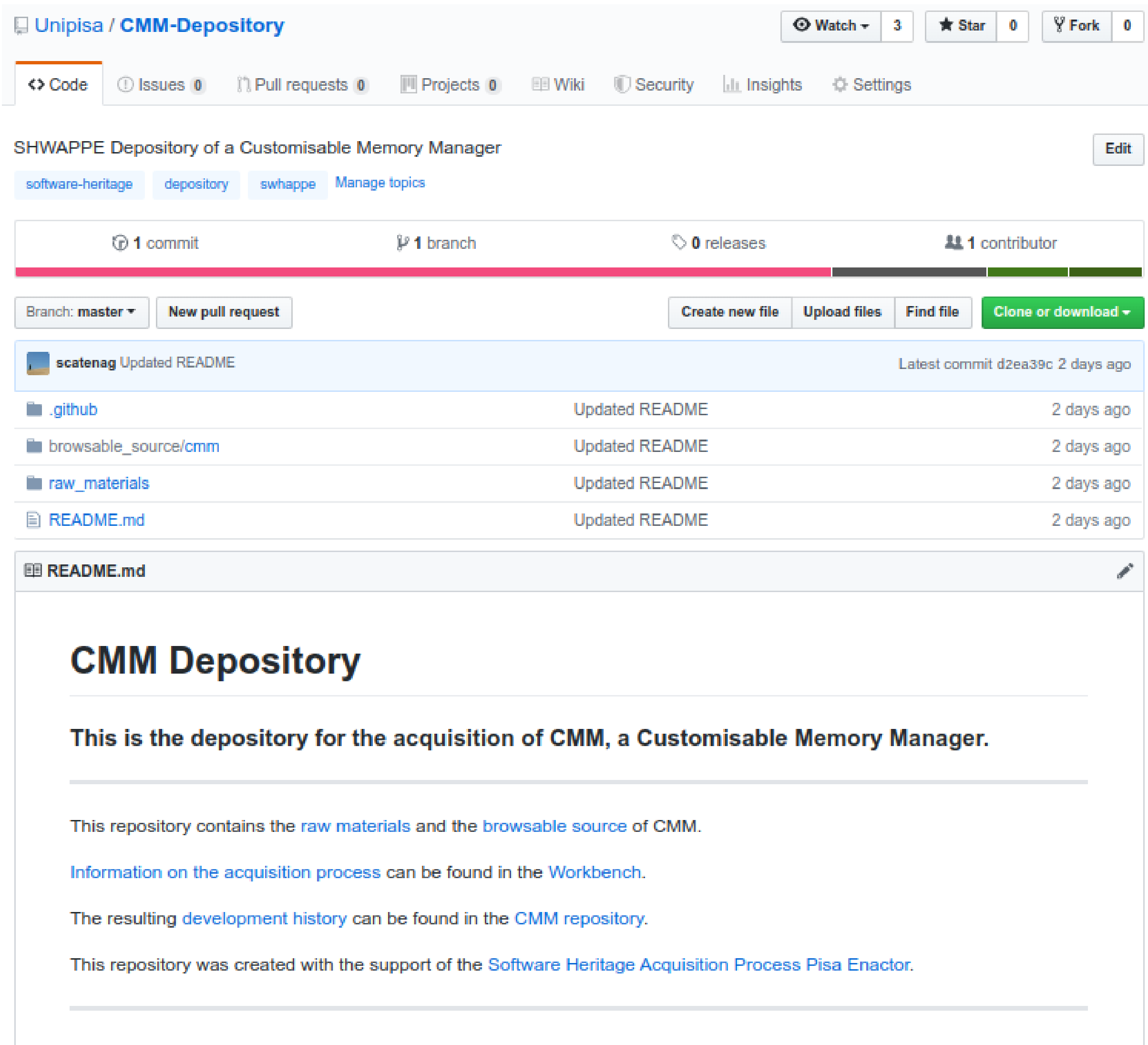


Figure 16: The final CMM Depository.

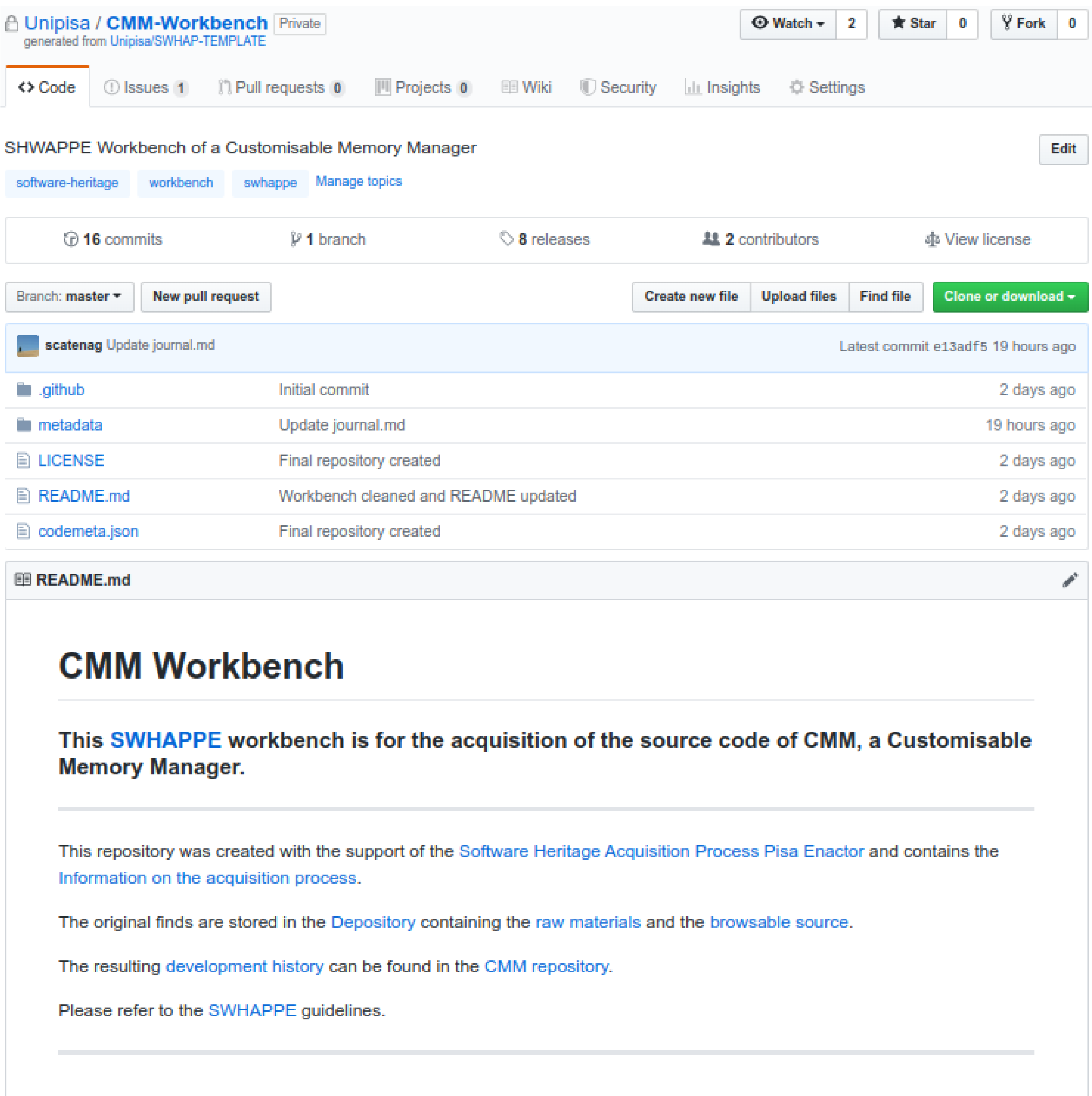


Figure 17: The final CMM Workbench.

```
curl -s -X POST https://archive.softwareheritage.org/api/1/origin/save/git/url/$repo_url
```

where **$repo_url** is https://github.com/Unipisa/CMM/.

A short time after (this may go up to a few hours for huge repositories), the archived software will be visible in the Software Heritage archive at

https://archive.softwareheritage.org/browse/origin/https://github.com/Unipisa/CMM

Fill the Workbench metadata

In order to preserve information about the curation process we have to fill the template files under the Workbench metadata. Starting from some template files (see Figure 18, left), we obtain what shown in Figure 18, right.

In particular we should create :

- a catalogue : metatdata/catalogue.md, where each item in the raw_materials should have a record describing its origin, the possible warehouse, their authors and collectors along with a description. The result of tree -a on raw_materials should be included;
- a journal :metatdata/journal.md, where each collect and curate action should be annotated;
- an actors registry: metatdata/actors.md, every person taking part in the process should be registered, with their roles, affiliations and contact information;
- a notepad : metatdata/journal.md where write possible information not covered by previous files.

5) Appendix A - Tools that can help

Here is a list of tools for code acquisition and curation that have been used during the initial experimentation of SWHAPPE:

- Used/suggested OCR:
  - Tesseract (https://github.com/tesseract-ocr/). It can be installed and used from command line. An API is also provided to use the OCR in a script.
  - OCR.space (https://ocr.space/). Online OCR and free API.
- Dedicated scripts:
  - DT2SG-Directory Tree 2 Synthetic Git (https://github.com/Unipisa/SWHAP-DT2SG). Creates the synthetic history of the software.
  - SWHAP-EXAMPLE(https://github.com/Unipisa/SWHAP-EXAMPLE)

Many other tools exist, and are currently under construction and will be loaded on the SWHAPPE repository on GitHub.

SW_NAME Journal

- **dd/mm/yyyy**
  - *Items:* Item Name.
  - *Actors:* Name Surname (role).
  - *Description:* Action done on the Depository.
  - *Notes:* Additional notes.

CMM Journal

- **06/05/2019**
  - *Items:* None
  - *Actors:* Guido Scatena
  - *Description:* Guido Scatena creates this repository (called SWH-CMM-LAB) cloning the structure from the template.
- **06/05/2019**
  - *Items:* email , ps-file, (https://github.com/Unipisa/CMM-Depository/tree/master/raw_materials/cmm.tgz) source code
  - *Actors:* Guido Scatena (Collector)
  - *Description:* Upload of *Items*.
  - *Notes:* On 02/03/2019 Giuseppe Attardi sends an email to Roberto Di Cosmo and Carlo Montangero. The email contains links to a paper in a ps-file and to the compressed source code. On, 09/04/2019, Carlo Montangero forwards Attardi`s email to Guido Scatena.
- **15/05/2019**
  - *Items:* CMM Depository Journal and CMM Depository Actors
  - *Actors:* Guido Scatena (Curator)
  - *Description:* Discovers a new author, reading the source code (changelog): Pietro Iglio.
- **20/05/2019**
  - *Items:* CMM Depository Journal and CMM Depository Actors
  - *Actors:* Guido Scatena (Curator)
  - *Description:* Discovers new authors (actually contributors) reading source code (copyright).
- **30/05/2019**
  - *Items:* CMM Depository Metadata
  - *Actors:* Guido Scatena (Curator)
  - *Description:* Filled metadata info in form of CodeMeta json file.

SW_NAME Actors

Name Surname

- *Affiliation*
  - *Current:* Example Departement
    - *Email:* surname@example.com
    - *Github handle:* @github
    - *Website:* http://www.example.com/~example/
  - *Historical:* Ancient Example Departement
    - *Email:* surname@ancient.example.com
- *Roles:* Author

CMM Depository Actors

Carlo Montangero

- *Affiliation*
  - *Current:* Dipartimento di Informatica, Università di Pisa
    - *Email:* carlo@montangero.eu
    - *Github handle:* @CarloQMontangero
    - *Website:* http://www.di.unipi.it/~monta/
- *Roles:* Collector

Carlo Traverso

- *Roles:* Contributor

Christian Heckler

- *Affiliation*
  - *Historical:*
    - *Email:* chh@plato.uni-paderborn.de
- *Roles:* Contributor

Giuseppe Attardi

- *Affiliation*
  - *Current:* Dipartimento di Informatica, Università di Pisa
    - *Email:* giuseppe.attardi@unipi.it
    - *Github handle:* @attardi
    - *Website:* http://www.di.unipi.it/~attardi/
  - *Historical:* Dipartimento di Informatica, Università di Pisa
    - *Email:* attardi@di.unipi.it

SW_NAME Catalougue

- **Item Name**
  - *Origin:*
  - *Warehouse:*
  - *Authors:* Name Surname
  - *Collectors:* Name Surname
  - *Description:*
  - *Notes:*

CMM Depository Catalogue Tree

```
.
├── attardi.ps
├── cmm.tgz
└── email_attardi.txt
```

CMM Depository Catalogue

- **attardi.ps**
  - *Origin:* http://usenix.org/publications/library/proceedings/c++94/full_papers/attardi.ps
  - *Authors:* Giuseppe Attardi,Tito Flagella
  - *Collectors:* Guido Scatena
  - *Description:* paper presented at USENIX C++ 1994, originally retrieved here as stated in Attardi`s email.
- **cmm.tgz**
  - *Origin:* http://medialab.di.unipi.it/ftp/cmm.tgz
  - *Authors:* Giuseppe Attardi,Tito Flagella
  - *Collectors:* Guido Scatena
  - *Description:* source code in compressed format, originally retrieved here as stated in Attardi`s email.
- **email_attardi.txt**
  - *Origin:* email
  - *Authors:* Giuseppe Attardi
  - *Collectors:* Guido Scatena, Carlo Montangero, Roberto Di Cosmo.
  - *Description:* text of the email sent on 02/03/2019 by Giuseppe Attardi to Roberto Di Cosmo e Carlo Montangero.

Figure 18: The CMM Metadata.

6) Appendix B - A few tips on Github

Git is a distributed version-control system for tracking changes in source code during software development. Here, we provide some references on *Git* and the GitHub platform.

For a review on GitHub key concepts, you can see the following glossary:

https://help.github.com/en/articles/github-glossary.

In order to fully exploit Github, you should install *Git* on your pc:

https://git-scm.com/book/en/v2/Getting-Started-Installing-Git.

This will allow you to use Git from command line. Even if it can be less intuitive, it's more powerful than working with the web interface: for instance, you can upload folders and files of any size, without the limitations of the latter. Furthermore, using Git commands allows for instantiating the process on any Git supported platform. For a review of the commands, please check the manual: https://git-scm.com/docs.

As an alternative, if you're using a Mac or Windows, you can download Github Desktop, which provides a comfortable GUI: https://desktop.github.com/.

For more information about the commit mechanism and how to see the log of changes, please see the following link: https://git-scm.com/book/en/v2/Git-Basics-Viewing-the-Commit-History.

To implement the process and separate areas, we chose to create two different branches (Depository and SourceCode) and get the corresponding repositories from them. Each branch has an independent commit history, thus the history of Depository and SourceCode is kept clean and easy to consult. Here is a discussion on how to see the branch history: https://stackoverflow.com/questions/16974204/how-to-get-commit-history-for-just-one-branch.

Bibliography

[1] Harold Abelson and Gerald J. Sussman with Julie Sussman. *Structure and Interpretation of Computer Programs*. Cambridge, MA: The MIT Press and McGraw-Hill, 1985, pp. xx + 542. ISBN: 0-262-01077-1 (MIT Press), 0-07-000422-6 (McGraw-Hill).

[2] Jean-François Abramatic, Roberto Di Cosmo, and Stefano Zacchiroli. "Building the Universal Archive of Source Code". In: *Commun. ACM* 61.10 (Sept. 2018), pp. 29–31. ISSN: 0001-0782. DOI: 10.1145/3183558. URL: http://doi.acm.org/10.1145/3183558.

[3] Giuseppe Attardi and Tito Flagella. "Memory Management in the PoSSo Solver". In: *J. Symb. Comput.* 21.3 (1996), pp. 293–311. DOI: 10.1006/jsco.1996.0013. URL: https://doi.org/10.1006/jsco.1996.0013.

[4] Ronald Burkey. *Virtual AGC - Changelog*. Available at http://ibiblio.org/apollo/changes.html. Spans years 2003 to 2019.

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[6] Leonard J. Shustek. "What Should We Collect to Preserve the History of Software?" In: *IEEE Annals of the History of Computing* 28.4 (2006), pp. 110–112. DOI: 10.1109/MAHC.2006.78. URL: http://dx.doi.org/10.1109/MAHC.2006.78.

[7] Diomidis Spinellis. “A repository of Unix history and evolution”. In: *Empirical Software Engineering* 22.3 (2017), pp. 1372–1404. DOI: 10.1007/s10664-016-9445-5. URL: https://doi.org/10.1007/s10664-016-9445-5.