ARCHAIDE

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D 7.2 Release of the final version of the mobile app (software) and the desktop front-end (software)

version: 2.2

Revision: Final

Work Package	**7**
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2.2	27.02.2019	Gabriele Gattiglia	Final revision

Disclaimer

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Table of Content

Abbreviations

WP: Work package

M: Month

UNIPI: Università di Pisa

UoY: University of York

UB: Universitat de Barcelona

UCO: Universitaet zu Koeln

TAU: Tel Aviv University

CNR: Centro Nazionale delle Ricerche

INERA: Inera srl

BARAKA: Baraka Arqueologos S.L.

Elements: Elements centro de gestio i difusio de patrimoni cultural

Executive summary

This deliverable describes all the functionalities available on both the ArchAIDE mobile app and the Desktop website which implement the technical solutions developed by the project in less than 3 years. The ArchAIDE mobile app and the ArchAIDE Desktop Website are the tools provided to end users to access the database and experiment with all the technologies developed in the project. The two functionally similar systems integrate all the software components developed in WP3, WP4, WP6 and WP7 into a single tool that can be used either on mobile devices or on personal computers. In more simple words, D7.2 represents what users see of the achievements of the project, the interface that allows users to navigate into the knowledge-base (i.e the reference database populated in WP5), searching and visualising all the data collected and digitised by the project, for instance, through dynamic infographic or 3D models; to recognise potsherds either by decoration or by shape; to store their data in order to quantify the pottery found in every user's assemblages, to share collected data with other researcher, etc. D7.2 represents the final outcome of the project for which the project itself will be judged by the users decreeing its success or its failure. For this reason, the work that is described in this document started at the very beginning of the project with the requirements analysis, carried out in WP2, and continued all over the project lifetime carrying on usability tests of the applications inside the project in cooperation with all the academic and professional partners, and outside the ArchAIDE project during the four multiplier events held at York, Cologne, Pisa and Barcelona. The target users of the ArchAIDE tools are mainly professional and academic archaeologists, as well as university students who can use the application for improving their domain knowledge and more in general citizens that can use the ArchAIDE systems for being more involved in the understanding of the archaeological heritage.

The ArchAIDE mobile app is currently available within a beta-testing program to a group of beta-tester identified by the partners. The official publication for the general public will take place after an accurate test activity (D8.1) and before the end of the project.

The ArchAIDE Desktop Website is available at the internet address http://archaide-desktop.inera.it and will be moved on http://desktop.archaide.eu as soon as the hosting infrastructure will be available.

1 Introduction

The present deliverable describes the mobile and desktop software applications developed in WP7. The target of the applications is the final user, an archaeologist collecting information about pottery sherds found in the field and trying to classify them. The mobile application includes tools for the acquisition of pottery sherds images and for automatic classification based on the decoration present on the surface, on the shape of the sherd fracture or on the stamp present on the sherd surface. The result of the automatic classification will be the suggestion of candidate decoration types (i.e. Genere 19. Settori puntinati) or candidate pottery form types (i.e. Dragendorff 18) or candidate workshops (i.e. 1725 - RUFIO) depending on the tool used.

The classification process consists in assigning a class from the Reference Database and a probability coefficient to a sherd where the semantic is, for example: "sherd 56478-89 at 70% is of type Dragendorff 18". The automatic classification processes are based on deep-learning networks trained with thousands of samples and running on autonomous systems (see D6.1, D6.2 and D6.3).

The first step for the definition of the software applications to be used by the final users was to analyse the archaeologists' way of managing real sherds, the workflow from the excavation to the results documentation, the context in which the activities were carried on and the related constraints (see D2.1). The design phase took into account the results of the analysis and was carried on as a User-Centred Design process where the priority was easy and intuitive access to the application's functionalities.

The software development methodology adopted by the project team was based on the iterated production of prototypes submitted to the project partners for evaluation. The feedbacks given by each partner and general discussions during meetings was used to review the design decisions and generate new prototypes. One of the major sources of inputs was the series of workshops and Training Open Days (D10.3) held with different groups of archaeologist from different countries (UK, Italy, Germany and Spain). During each workshop, the intermediate results were presented and demonstrated to 20-30 experienced archaeologist coming from the specific country. The suggestions and complaints collected during the workshops were discussed during the project meetings and became inputs for the design and development team. As an example of the way in which the process progressed, in the last year the development team produced about 80 distinct versions of the ArchAIDE mobile app each containing major and minor changes.

The WP7 design and development activities started on the mobile app first and moved on the desktop application only after all the functionalities and user-interface issues was cleared and the data visualisation task (Task 7.5) produced its results.

2 Analysis and design

Since the beginning of the project, the main focus was on what kind of functionalities would be provided by the ArchAIDE tools to the archaeologists and when such tools would be probably used in their daily excavation, lab and reporting work.

The reference scenario (D2.1) assumed the following, very high level, definitions of the archaeologist's workflow:

- During the excavation of a **site**, pottery findings may be useful to understand the context and define the excavation strategy. For example, being able to date a pottery sherd while excavating may help in identifying and dating a context.
- Pottery sherds belonging to the same context compose an **assemblage**, i.e. artefacts recurring together at a particular time and place.
- Pottery sherds contained in an assemblage once washed and cleaned, are analysed to understand the form of the vessel they belong to, the time it was produced, the production workshop, etc. The analysis activities take into account much information among which:
    - *The **characteristics** of the sherd material*
      from a broad analysis of the sherd, the archaeologist may identify if it belongs to an open or closed form and the general classification (i.e. the belonging to a ceramic class, such as amphorae, terra sigillata, etc.). Through the analysis of the composition of the fabric, it is possible to understand the production area, etc.
    - *The **decorations** on the sherd surface (if present)*
      Decorations help specialists in classifying and dating pottery on the base of subjects, colours, etc.
    - *The **shape** of the sherd with special attention to the fractures*
      Studying the fracture of a sherd it is possible to understand which part of the original artefact it belongs to (rim, handle, body, base, etc.). At the same time, comparing the fracture with the drawings of the classified forms described in the pottery catalogues it is possible to identify the specific form of the original vessel.
    - *The **stamps**, complete or partial, on the sherd*
      Stamps, when present, tell the archaeologist who, where and when was produced the vessel. Stamps are recognised using specialised catalogues.

The application design started with the general architecture of the final system and then covered the details of each component. In particular, the design and software development methodology adopted was Agile and based on the **Scrum framework**.

The design of the general architecture was essential to determine which systems would be implemented, the technologies to be used and how the systems would interact with each other. The global picture of the work to be done was used to plan the release of incremental versions of the global system and for each component.
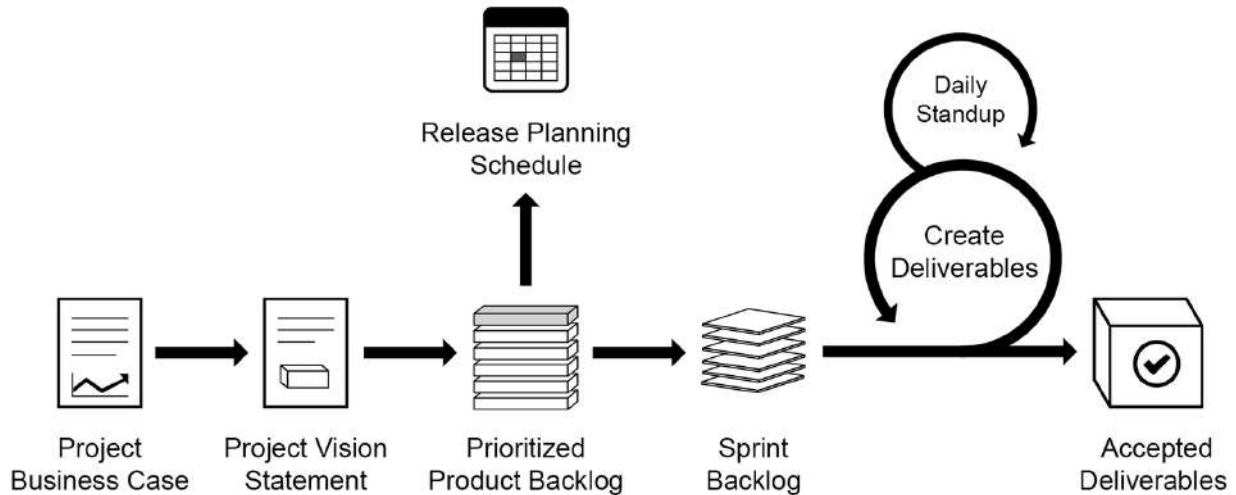
The design process produced the *epics* and *stories* that populated the **Backlog** for each application (product) composing the ArchAIDE system. The development team grouped all the entries of the backlog (stories: functionalities of the application) in **sprints** i.e. development cycles during which the team implements all the functionalities of the specific group and releases the software to the test group or final users. The process continues until all the functionalities and applications are fully developed and tested. At the end of each sprint, all the involved people held a review of the sprint in order to tune the organization of the team, plans, etc.

The methodology roughly described in the previous paragraphs was extremely useful to plan the work to be done by the development team and in the distribution of the activities among the team members. The whole process was supported by the **Jira Agile Management Tools** (https://www.atlassian.com/agile/project-management), a complete suite of cooperative tools for the creation, management and monitoring of a Scrum project.

2.1 Requirements

The discussions on the scenario (WP2) and the results achieved in WPs 3 and 6 brought to the identification of the main requirement areas concerning the functionalities and the expected user experience. In particular, the areas emerged as important were:

- **User-experience**
  The user usual workflow, the style of the user interface, the influence of the context where the application will be used, etc.
- **Anonymous vs. registered**
  Registration is required or not? Which profile information do we need to collect about the user? Which are the functionalities for anonymous users? Which tools and services will be available to registered users?
- **User collected information**
  Which information may be collected by the user and stored in the app (or server)?
- **Online vs. offline (only app)**

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[1] Courtesy of WikiMedia Commons https://commons.wikimedia.org/wiki/File:Scrum_Flow_for_one_Sprint.png

Is the app online only (useless when the device is offline)? or are there functionalities available even when the Internet connection is unavailable?

- **Closed vs. Open Data**
Who may view the data collected by a user? Would be possible for a user to hide or publish his/her own data?

2.1.1 User-experience

Both the mobile and the desktop app are thought for supporting archaeologists in their daily work activities. Consequently, user-interface graphics has been designed for being minimalist and focused on clean, easy to read and intuitive interfaces.

The interface theme of the ArchAIDE Desktop application is based on the ArchAIDE Project Site (https://archaide.eu) published at the beginning of the project. The communication contents such as brand, images, news, video, etc. are all concentrated on the home page. The internal pages of the theme are simple and clean therefore particularly suitable to accommodate the search and classification tools proposed by the project.

For the mobile app, the base strategy was to adopt the standard guidelines for Android[2] and iOS[3] promoted by Google and Apple. The choice guarantees a good quality of the result and that the look-and-feel and behaviour of the ArchAIDE App will be consistent with the hosting platforms.

The design took into account the following main requirements:

- Optimisation of the interface for smartphone and tablets.
- Optimisation of the interface for portrait and landscape orientation.
- Providing access to the reference database and to the classification tools to all users, including anonymous.
- Quick access to automated classification tools.
- Quick access to the recent activities (i.e. the sherd classified, the last database entries visualised, etc.).
- Quick access to the user's collected data (only for registered users).
- Capability to check the synchronization status (i.e. is everything saved on the server?).

If the synchronization of the device will take place asynchronously when the device is online (3G/4G or WI-FI), the initialization of the app will take place the first time it will be opened and consists in initializing the reference database. The initialization will allow offline access to the main catalogue data.

Multimedia materials (images) will be uploaded on the device opportunistically and asynchronously when needed in order to avoid the overloading of the device filesystem.

2.1.2 Online vs. Offline behaviour

The ArchAIDE mobile application may be used by archaeologists in many contexts where the connectivity is not available such as storehouses or remote rural areas. In such conditions, the use of the app may be limited to the acquisition of materials (i.e. creating new sherds from pictures taken with the device) or to the browsing

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[2] https://developer.android.com/design/
[3] https://developer.apple.com/design/human-interface-guidelines/ios/overview/themes/

of the Reference Database to check the definition and characteristics of specific ceramic types, decorations or stamps.

When opened the first time, the mobile app initialises the local database with all the data from the Reference Database excluding the images. The images related to database records will be downloaded opportunistically when the device is online and the user visualises a specific record.

The registered users will be able to collect information about their own sites/assemblages/sherds that are stored in the local memory of the device and, if the device is online, on the ArchAIDE server. The app registers the information locally when offline, the information will be later registered on the server when online.

The synchronisation process between the device and the server is bi-directional. All the information registered on the device are sent to the server immediately (i.e. on "save" action) or when the device comes online. Any change to the data on the server concerning the Reference Database (i.e. new records, updating of existing records etc.) or the user specific data manipulated through the ArchAIDE Desktop tools, will be sent to the device.

As the synchronisation process may generate confusion about what is synchronised and what it isn't, the app provides a tool to monitor the synchronisation process.

2.1.3 Anonymous vs. Registered users

One of the initial decision was to make all the tools available freely without any constraint. This essentially means that users don't need any registration to access the Reference Database data or automatic classification tools. At the same time, the possibility to collect pictures of sherds, classify and store them was recognised as a useful feature that may allow users to keep track of their work and reuse the collected information later on. The adopted approach is to let everybody open and use the tools and reserve to registered (known) users the ability to store information about sherds. After the user is logged, the behaviour of the app changes and the user will be able to access all the site/assemblage/sherd information stored on the device and on the server. For a registered user, it is also possible to save the classification information obtained from the automatic classification tools.

2.1.4 User collected information

The goal of the mobile and desktop app is the classification of pottery sherds found on a site. As described in previous paragraphs users may want to use the application simply as a tool for one-shot recognition of a sherd but we believe that the application would be extremely useful when the data are collected and stored for future uses. If we want to record information about a **sherd** we need to register it together with a description of the context: which **assemblage** it belongs to and in which **site** it was found. In order to identify the context in which a sherd was found, the app assumes the following hierarchy:

- Site
  - Assemblage
    - Sherd

A sherd belongs to an assemblage that comes from a site. Any registered user owns at least one default site (i.e. "*Default Site*") that contains at least an assemblage (i.e. "*Uncategorised*") where the sherds may be saved. Using the app or the functionalities of the desktop application, the users will be able to define their own sites and assemblages and or update the existing ones.

The process of adding new records through the app either sites, assemblages or sherds, must be easy and fast because the user is using a device where writing is time-consuming. For each entity the collected information is the essential ones like the following:

- **Site:**
  - Name
  - Address
  - City
  - Region
  - Country
  - Coordinates (latitude, longitude edited through a map)
- **Assemblage:**
  - Name
- **Sherd:**
  - Code (sherd name)
  - Ceramic class
  - Form
  - Part
  - Notes
  - Images (loaded using the device cam or galleries)
  - Fracture profiles (captured during shape recognition)
  - Classification info (defined through automatic classification or manually)

In the typical scenario, a user accesses the decoration recognition tool, takes an image of a sherd surface using the device cam, analyses the results of the classifier, selects one or more option and then saves it as a new sherd. The same may be done using shape recognition or stamp classification tools.

2.1.5 Closed vs. Open Data

Data collected by the end users are by definition private and cannot be published. All the system components are designed and implemented to comply with this important privacy statement. On the other hand, an important goal of the ArchAIDE Project is to publish massive open-data on pottery as the result of the cooperation of a community of archaeologists from all around Europe.

The dreaming scenario is the one in which hundred thousand sherds are stored in the ArchAIDE Database together with pictures, profiles, classification information, etc. and a large part of the database may be published as open-data through specific API and/or as linked open-data from a triple store.

At this purpose, the creation and update tools for sites and sherds will include a "**Publish as open-data**" boolean field that users may use to provide their contribution to the community.

2.2 General Architecture

As shown in the image below, the ArchAIDE ecosystem is a composition of mobile and server-side applications interacting through an API server that mediate all the communications and keeps track of the activities.
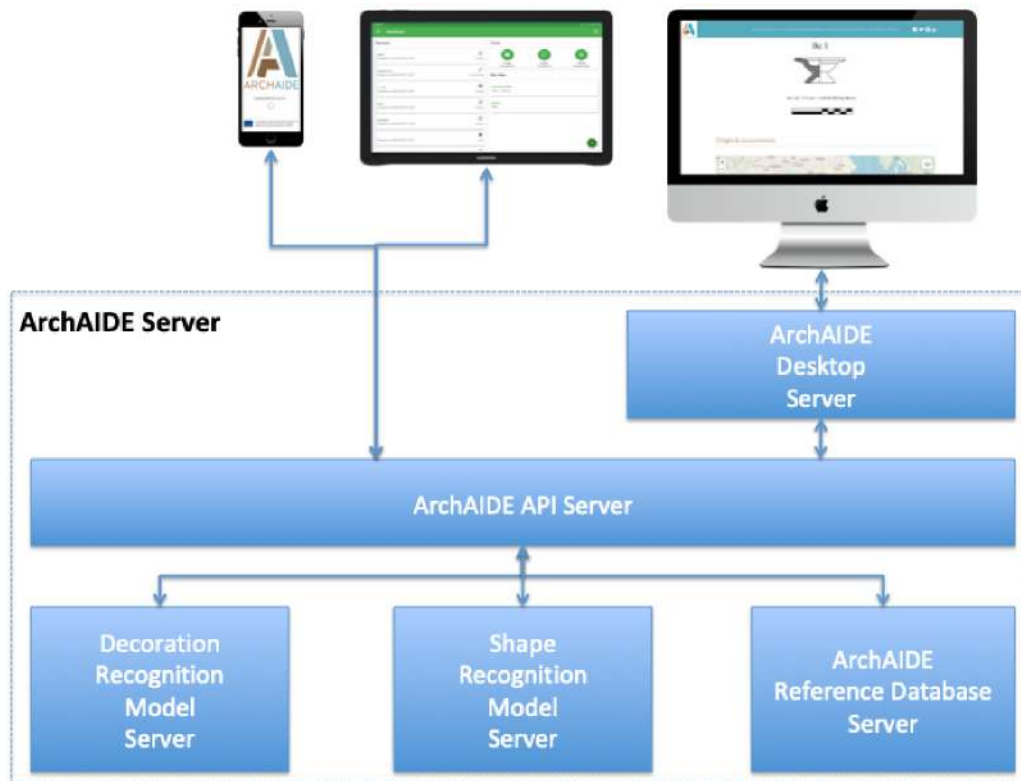
Fig. 2 - ArchAIDE Server Components

On the client side, the mobile application and the desktop web server call the API services to register and authenticate users, download snapshots of the database, search & retrieve information, store user collected data, request an automatic classification, etc.

The access to the ArchAIDE API Server is secured via an OAuth2 authentication method and may serve any client through an HTTP/REST protocol. The major benefit coming from the API is to provide a uniform and consistent interface on which it is possible to implement any kind of client application like, for example, open-data server, bulk uploading, monitoring tools, data-mining tools, etc.

The components of the ArchAIDE Server are the following:

- **ArchAIDE Desktop Web Server**
  The desktop web server serves a website where content management and interactive tools coexist in the same context. The site is supposed to contain information about the ArchAIDE tools, on the progress on the tools evolution and on the new data added to the Reference Database. At the same time, the site provides the same search and classification functionalities implemented in the mobile app. At this purpose was decided to adopt a Portal Server as a framework to implement a composite Web Application. In particular, it was selected **Liferay Portal 7.1** as the base infrastructure integrated with CAS[4] to support the single-sign-on of the users. The theme used for the desktop website is the same used for the project site https://archaide.eu in order to maintain a uniform and recognizable look-and-feel. In Liferay, pages are composed of functional blocks (portlet) positioned in specific positions of a predefined layout. To build the site we used content portlets (piece of static text, blog

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posts, etc.) and custom portlet implementing the ArchAIDE Tools: search in the database catalogues, decoration/shape/stamp classification, site/assemblage/sherd management, etc.

- **ArchAIDE Reference Database**

  The Reference Database is the cornerstone of the classification process and defines the reference classes for types, decorations and stamps. This application, developed in WP3 and described in D3.1, allows the ArchAIDE Project experts to maintain a database containing the information extracted from online and paper catalogues. The content of the database is growing continuously as a follow up of the activities in WP5. Each class in the database contains textual information (characteristics, chronology, references, etc.) but also relations with other entities such as places, type/subtype, related stamps, related decorations, etc.

- **Shape Recognition Model Server**

  The shape recognition model is a deep-learning neural network trained with information coming from the reference database and from hundreds of sherd profiles (D6.3). The very complex task carried out by the model is to identify the ceramic type to which a sherd might belong, a detailed description of the model and the technologies used may be found in D6.2 and D6.3 The model server is a web server implementing the type prediction as a unique service. The input to the prediction transaction is an SVG file representing the internal and external profile of a sherd fracture. The result, returned as a JSON array, is a list of ceramic types identifiers paired with a probability index. This server is hosted on a dedicated virtual machine.

- **Decoration Recognition Model Server**

  The decoration recognition model is a deep-learning neural network trained with many thousands of classified images of medieval and postmedieval majolica (D6.1). The goal of the model is to identify the class of decoration to which the image belongs to (detailed description in D6.1 and D6.3)). The identification of the decoration class is precious for archaeologists because implies a very accurate dating of a sherd. The model server is a web server implementing the type prediction as a unique service. The input to the prediction transaction is an image of the sherd surface. The result, returned as a JSON array, is a list of decoration class identifiers paired with a probability index. This server is hosted on a dedicated virtual machine.

3 ArchAIDE Mobile Application

The mobile application is the result of Task 7.3 "*Implementation of the mobile application*" and was carried on by **Inera** with the collaboration of **CNR** and **TAU**. In particular, CNR provided the required support to integrate the libraries for the image manipulation developed in Task 7.2 "*Implementation of the 2D acquisition and the 2D drafting components (mobile tool)*" used to prepare the images used by the shape and decoration recognition tools. TAU supported the Inera team in installing and integrating the deep-learning models used by the prediction functionalities.

3.1 Splash screen, user dashboard and main menu

The App starts from a "***splash screen***" showing the project logo and the reference to the funding institution and program. The splash screen is the place where is carried on the synchronisation of the app with the ArchAIDE Server and thus all the related messages (i.e. "Loading …", "Connection error …" etc.) will be shown.

Fig. 3 - Splash screen + Loading

The very first synchronization may take a while (one to two minutes) because the whole Reference Database has to be downloaded from the server and initialised. The subsequent synchronisations are usually quite fast because it applies only to the changes occurred in the period between the first synchronization and the subsequent.

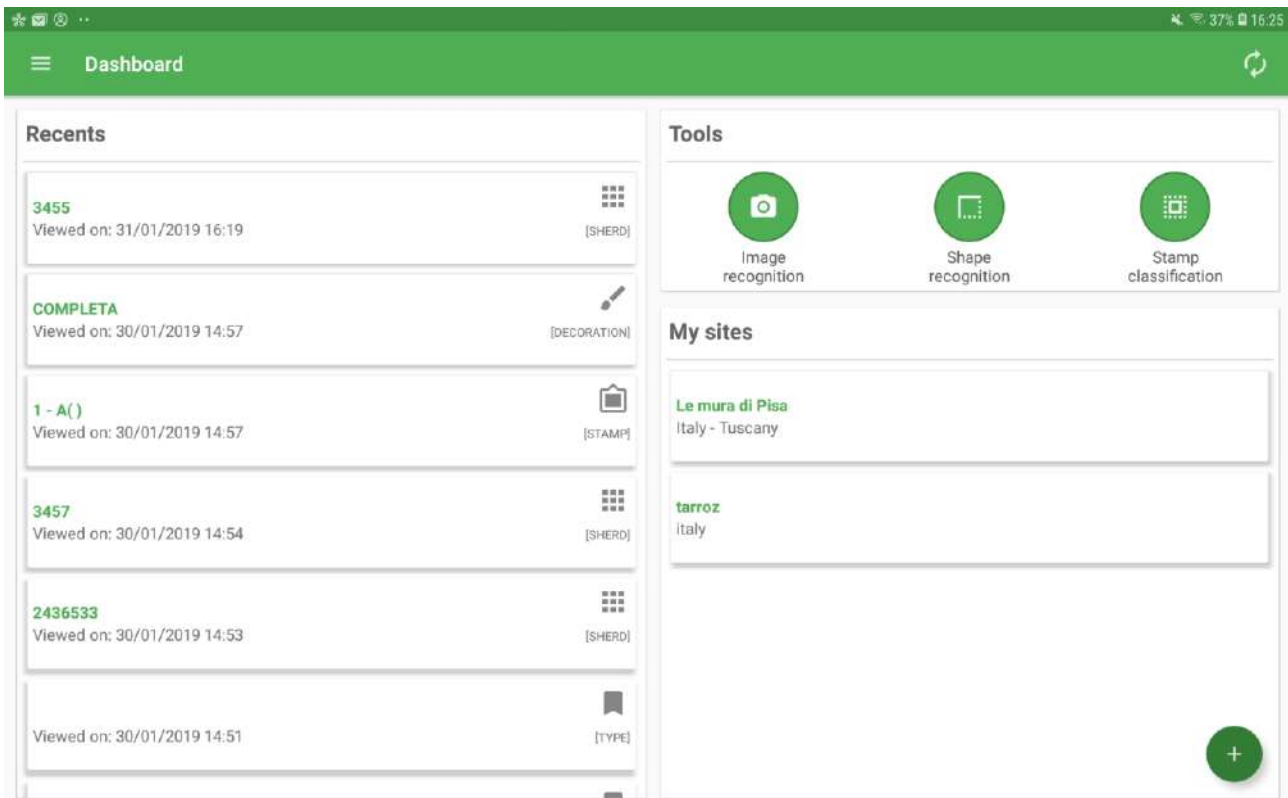From the splash screen, the user is automatically addressed to the **Dashboard** i.e. the home page of the App (see the picture below).

Fig.4 - ArchAIDE's mobile App dashboard

The dashboard was designed to support the user in his/her daily work providing quick access to the entities on which he/she is working, to the classification tools and to the users collected information (sites). The three areas composing the dashboard are:

- **Recent**
  This area contains the list of the entities (sherds, database records, etc.) visualised or edited by the user, ordered from the most recent to the oldest. Tapping on the entity will open the entity visualiser. The idea is that the user returning to the dashboard may access directly the entities he/she was working on the last time he/she accessed the app or a few minutes before.
- **Tools**
  In this area are shown the major tools provided by the App. The goal is to invite users to access and try them, in particular for newbies. Tapping on the tool icon, the tool interface will be open. The same may be achieved through the main menu.
- **My sites** (authenticated users)
  Authenticated users will find here the list of their personal sites used to store sherd information. Using the "+" button the user will be directed to a form for the creation of a new site. The "swipe" action on a site button will show the "basket" button for removing the site itself. It is important to note that a site may be removed only if it doesn't contain any sherd. Finally tapping on a site button, the **Site viewer** will be open.

Fig. 5 - The swipe action for deleting a site

- **Tips&Tricks** (anonymous users)
  Anonymous users will see, in the right lower area of the dashboard, a message synthetically describing the app and the opportunity to register and become a known user.

Tools

Image recognition | Shape recognition | Stamp classification | Knowledge-Base

Tips & Tricks

Welcome in ArchAIDE

ArchAIDE is an European Union funded project within the Horizon 2020 research and innovation program (Grant Agreement N. 693548).
Using the ArchAIDE Tools, you will be supported by intelligent agents in the identification of the decoration class or the form type of a pottery sherd starting from an image eventually taken with your device cam. The automatic classification is based on the classes defined in the Reference Database developed by the ArchAIDE Project and populated with data from online and paper catalogues.
As an anonymous user you are missing the capability to store your sherds in the device and on the ArchAIDE Server. The registration is absolutely FREE and gives you a set of useful functionalities for the documentation of your pottery sherds.
If you like, as a registered user you may help the ArchAIDE team to improve the intelligent engines with new training data and publish your results as open-data.

Fig.6 - Tips & Trips help anonymous users in knowing the App's functionalities

The application main menu is positioned on the top-left corner of the dashboard as a "hamburger" button[5] (see left image below). The main menu allows to access the catalogues of the knowledge-base, the recognition and classification tools and the application settings (see right images below).
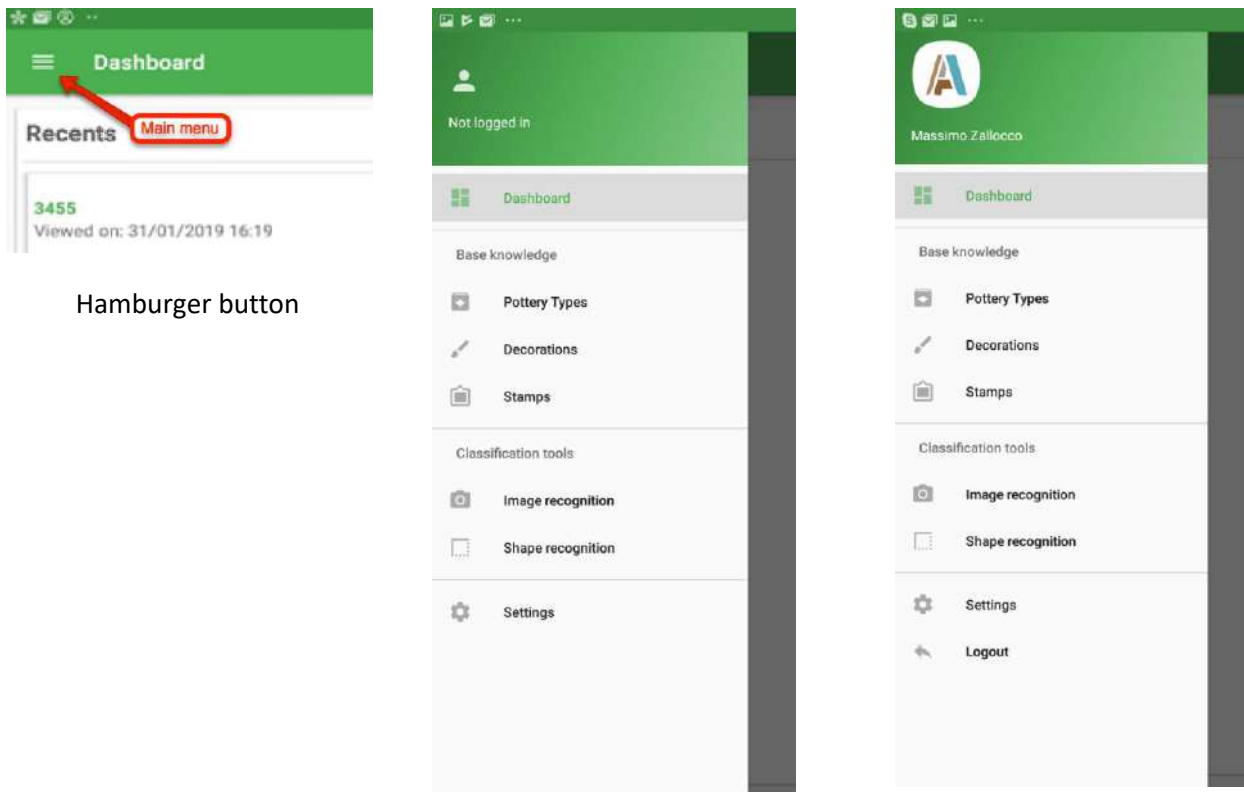
Hamburger button

3.2 Synchronisation

The synchronisation process is seamlessly carried on in the background each time the device is connected to the internet via WI-FI or 3G/4G. The hidden behaviour of the synchroniser is useful in standard conditions because everything happens without the need of user intervention, but if something goes wrong while using the app the users may be doubtful about the actual status of the collected data.

Tapping on the sync button on the top right corner of the Dashboard (see left image below) the user will access the Synchronisation monitor (see right image below). The page lists the main synchronisation actions (upload on the server, delete from the server, download from the server) on the relevant entities collected by the user (site, sherds, depictions, etc.). When everything is fine, the cloud icon on the left, for each line, will be green. If something goes wrong (for example connection lost during sync) or if the app is currently used in offline mode, the clouds becomes red for each sync action not yet finalised.
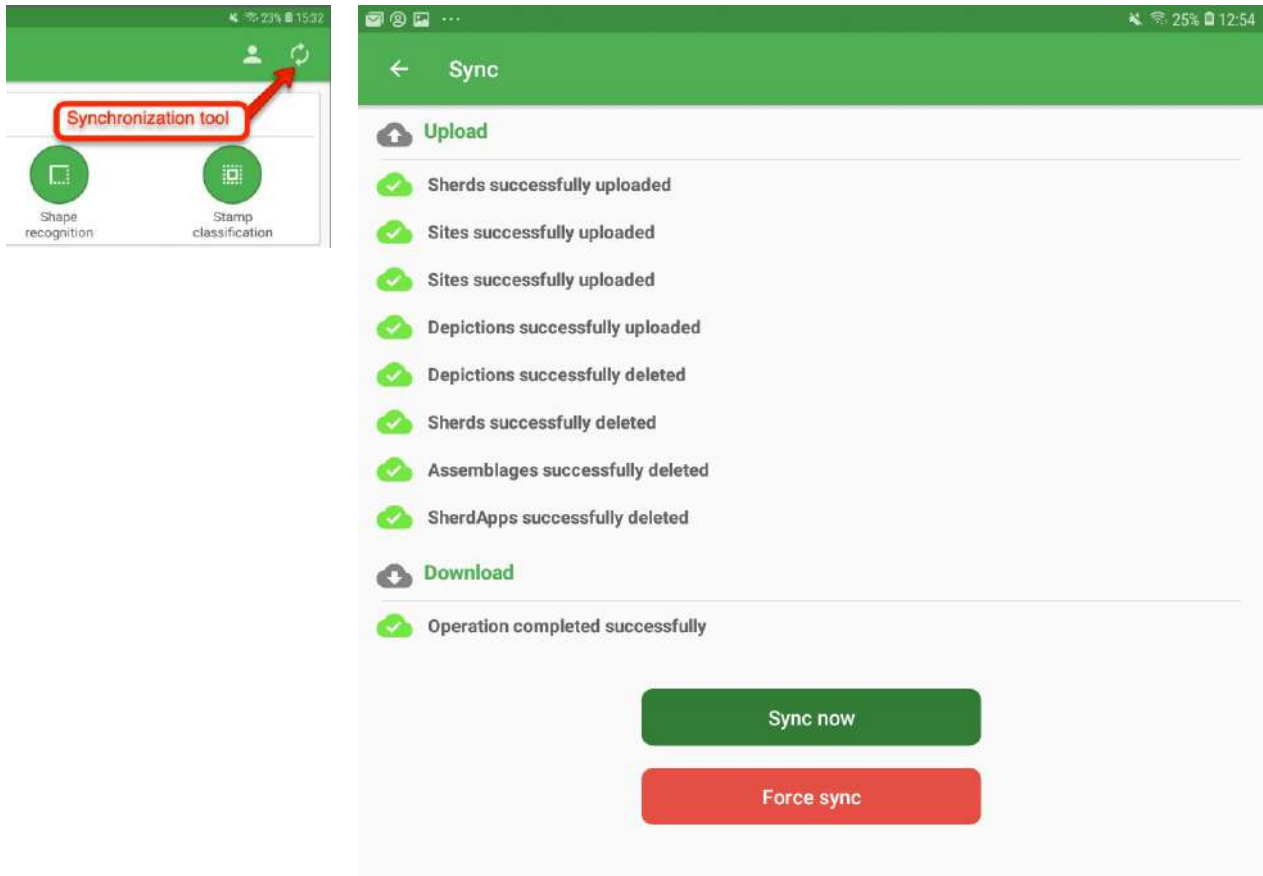
If the device is connected to the internet and some of the clouds are red (sync error) the user may start the synchronisation manually ("Sync now") or, in case of serious problems, re-initialise the device data ("Force sync").

3.3 User login and registration

Authentication and user registration may be accessed from the "user" button on the top right-hand side of the dashboard (left image below).

If the user is already registered, he enters username and password and then taps the Login button. On a successful login, the user will be redirected to the Dashboard.
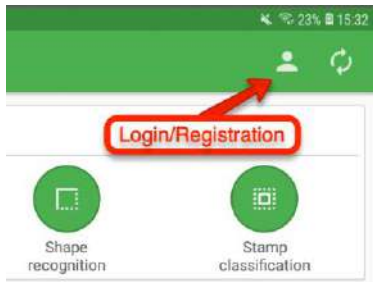
User Button
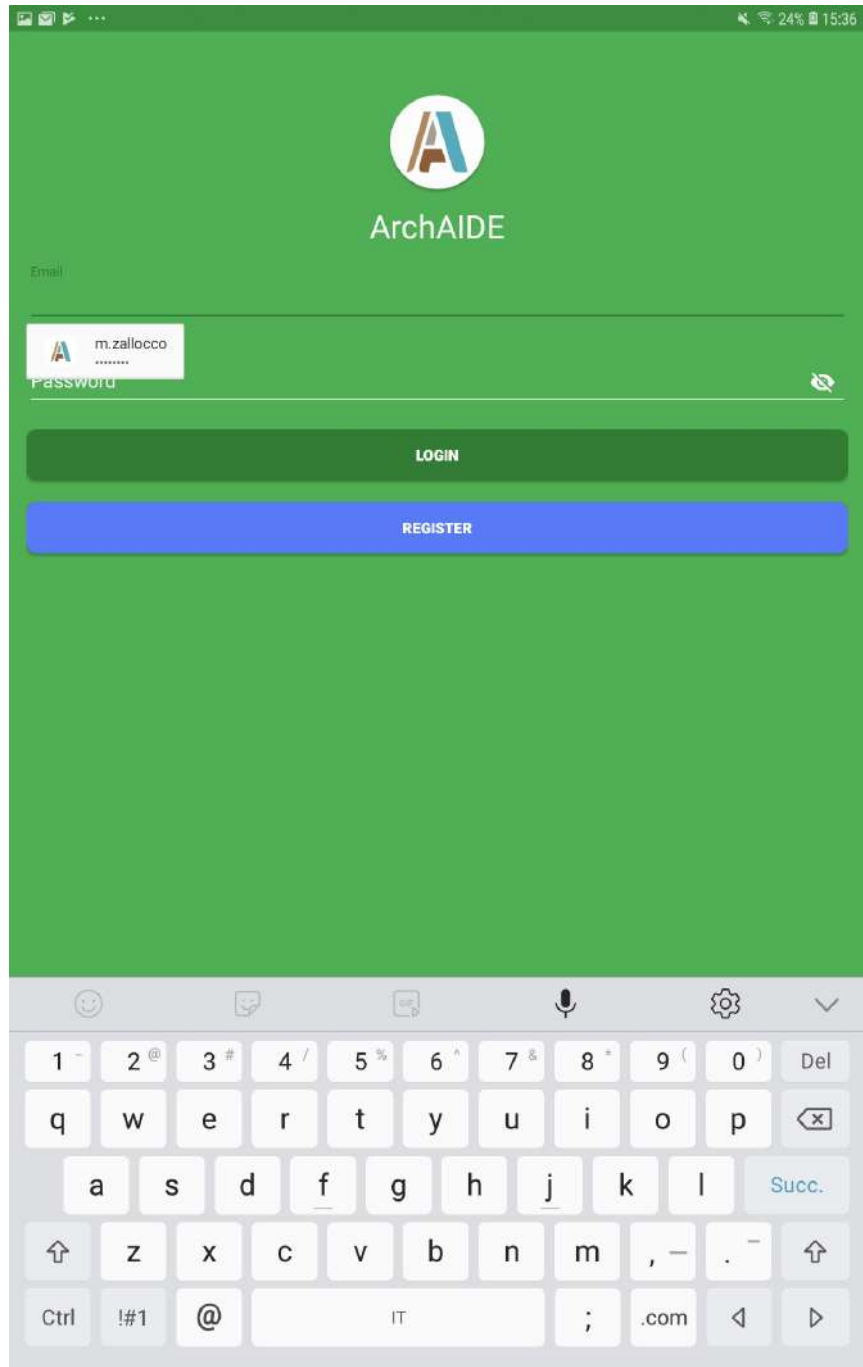
After the first login, the user remains logged in even after closing and re-opening the application. To force the need for a new login, the user should log out (last item in the main menu) before closing the application.

Users that are not yet registered, using the "Register" button will access the registration form as shown in the picture below.
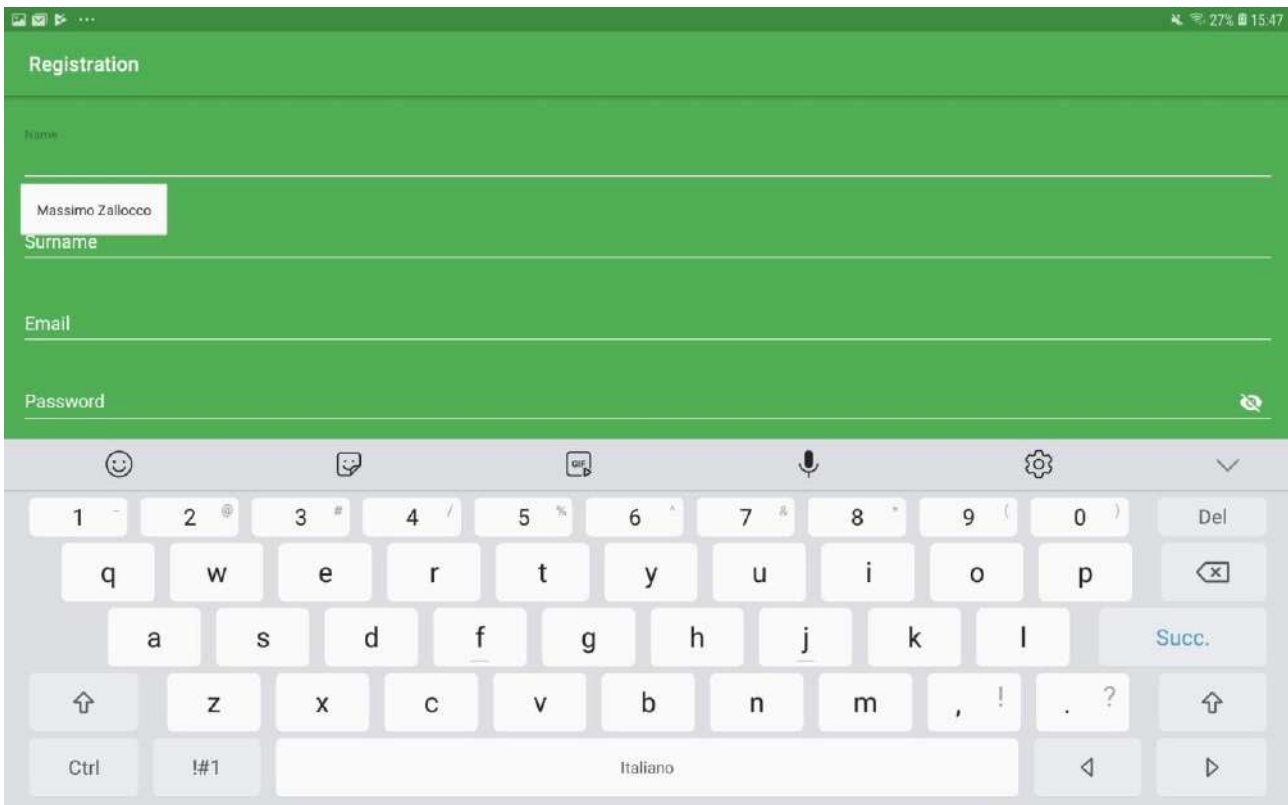
Fig.10 -The Registration form

The registration of a new user requires only a few non-sensible data such as name, password, email, privacy. In order to activate the account, the system will send an email, to the submitted address, containing a validation link.

3.4 Knowledge-base

The ArchAIDE knowledge-base is a collection of search & retrieval tools that allows accessing the database of reference classes for types, decoration and stamps. The defined classes derive from online and paper catalogues that were used to populate the "Reference Database". A team of expert archaeologists and researchers are continuously working on the database extending the catalogue and refining the definitions.

When accessed from the "Tools" area of the dashboard, the knowledge base contains a brief description and the buttons to access the catalogues (see picture below). From the main menu, it is possible to access the specific catalogues directly.
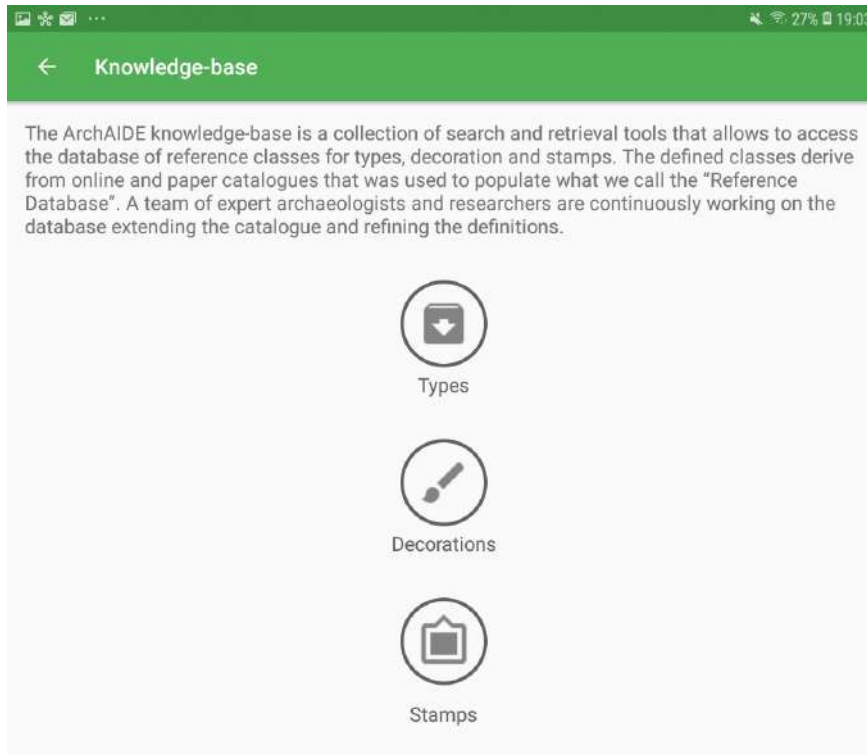
Fig.11 -The Knowledge-base home

3.4.1 Types

The search & retrieval interface for the **type catalogue**, shown in the image below, provide search field and filters to isolate types of interest.

The "keyword" search field (top of the form) is intended to apply to all the text fields of type records such as "name", "distinctive features", "period", "origin", "occurs", "equivalents". The filters are related to the main classification info such as:

- Ceramic class (i.e. Amphorae, Terra sigillata, Maiolica di Montelupo, …)
- Primary function (i.e. Transport, Food preparation and Consumption, …)
- Form (i.e. Jar, Cup, Dish, etc.)

The result set is updated continuously while the user changes the values in the search form.

Tapping on one of the results in the list, the user will be directed to the detailed description of the selected type.
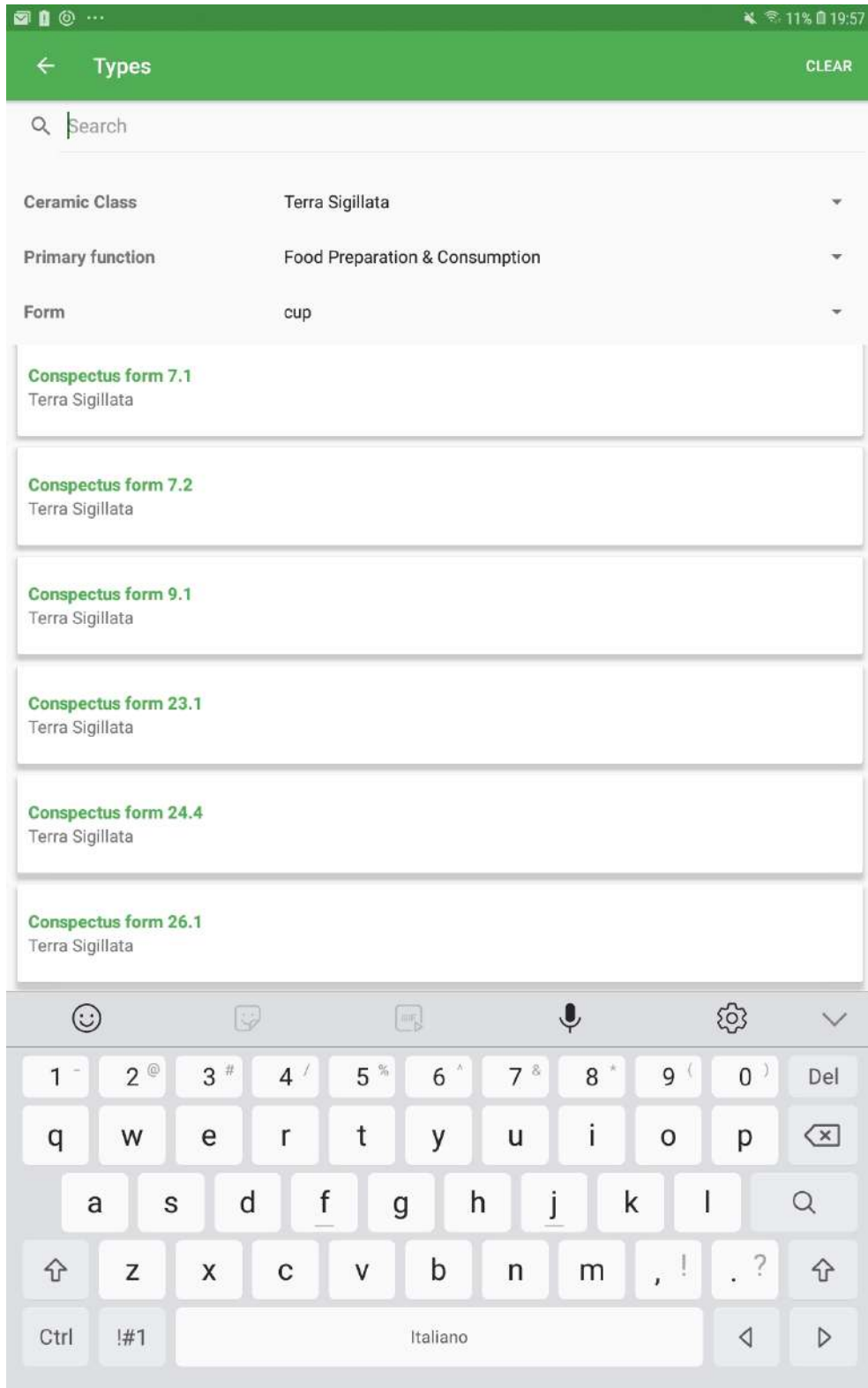
The detailed description of a type, see image below, contains all the relevant fields of the corresponding database record and the associated depictions.
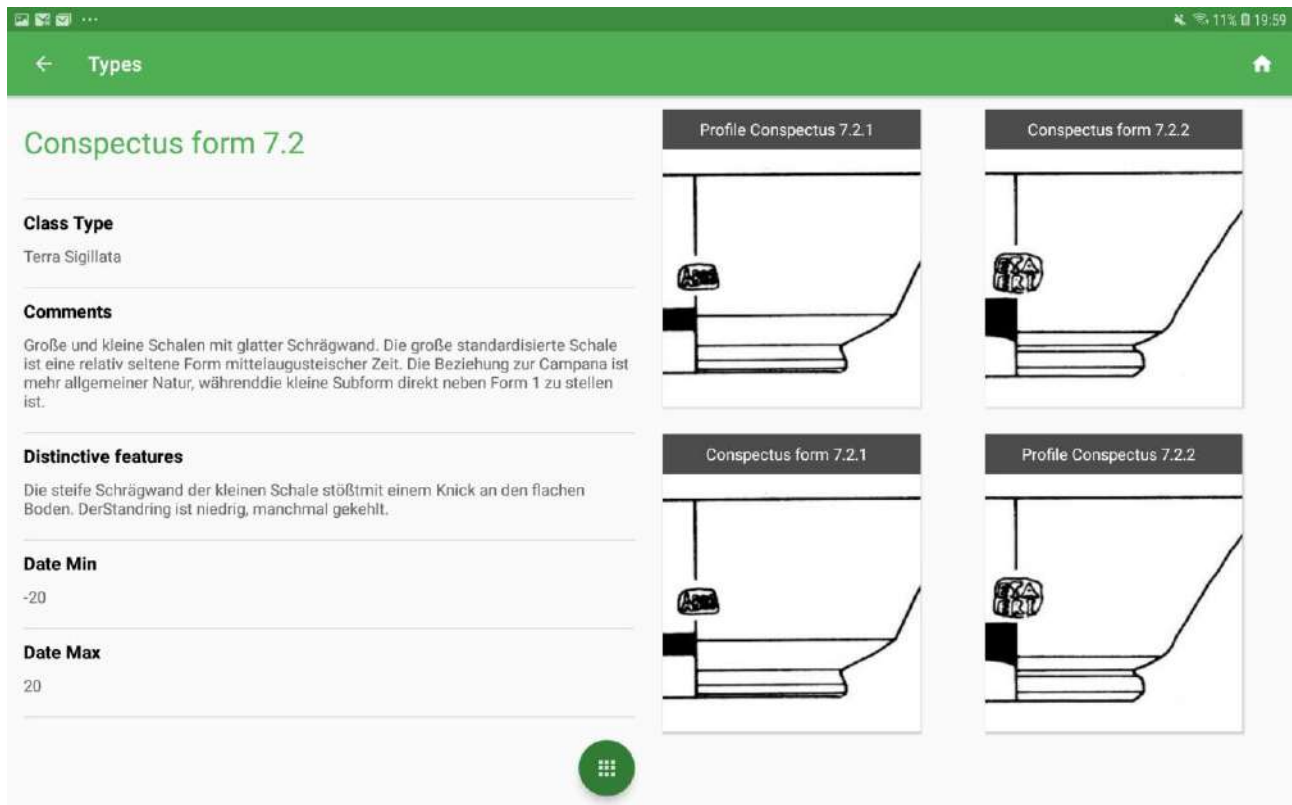
3.4.2 Decorations

The search & retrieval interface for the **decorations catalogue**, shown in the image below, provide search field and filters to isolate decoration classes.

The "keyword" search field (top of the form) is intended to apply to all the text fields of type records such as "name", "definition", "period description", "colour description". The filters are related to the main classification information such as:

- Decoration form (i.e. Painted, Incised, Burnished …)
- Colours (i.e. White, Green, Yellow, …)

The result set is updated continuously while the user changes the values in the search form.

Tapping on one of the results in the list the user will be directed to the detailed description of the selected decoration class.

The detailed description of a decoration class, see image below, contains all the relevant fields of the corresponding database record and the associated depictions.

3.4.3 Stamps

The search & retrieval interface for the **stamps catalogue**, shown in the image below, provide search field and filters to isolate stamps of interest for the user.

The "keyword" search field (top of the form) is intended to apply to all the text fields of type records such as "name", "definition", "period description", "workshop".

In particular, the search engine allows to make searches including wildcard characters in order to match the text (for "Name stamps") contained in the stamp itself. The scenario is the one in which the archaeologists find a sherd containing a stamp but only part of the name is readable or almost readable. To search a pattern like "ACCU …. R . S" (dots represents unreadable characters) the search engine allows to represent it as "ACCU%R_S" meaning "ACCU" followed by any character, then "R" followed by one character and finally "S". Searching for this pattern allows identifying the stamp "ACCU ILARUS". The wildcard characters that may be used in the keyword field are the following:

- **%** for zero, one, or multiple unknown characters
- **_** for a single unknown character

To activate the pattern search on the stamp text, the first character of the pattern should be **#**.

Examples of patterns may be the following:

- Typing "**#a%**" finds any values that start with "a"
- Typing "**#%a**" finds any values that end with "a"
- Typing "**#%or%**" finds any values that have "or" in any position
- Typing "**#_r%**" finds any values that have "r" in the second position
- Typing "**#a_%_%**" finds any values that start with "a" and are at least 3 characters in length
- Typing "**#a%o**" finds any values that start with "a" and ends with "o"

The search is case-insensitive.

The filters are related to the main classification info such as:

- Stamp type ("Name stamp" or "Pattern mark")

The result set is updated continuously while the user changes the values in the search form.

Tapping on one of the results in the list the user will be directed to the detailed description of the selected stamp.

The detailed description of a stamp, see image below, contains all the relevant fields of the corresponding database record and the associated depictions.

3.5 User collected information

Only authenticated users may collect and store data through the app. The information about sherds should be registered under a specific assemblage that belongs to a site. All the registered users own at least one site (i.e. "Default site") in which it exists at least one predefined assemblage (i.e. "Uncategorised"). Sites and assemblages are the minimum context information required to store a sherd.

3.5.1 Site

The Dashboard for authenticated users contains the list of user's sites (My sites). Tapping on a site item, the site viewer (left image below) will open. The only required information about a site is the location represented as an address and coordinates.
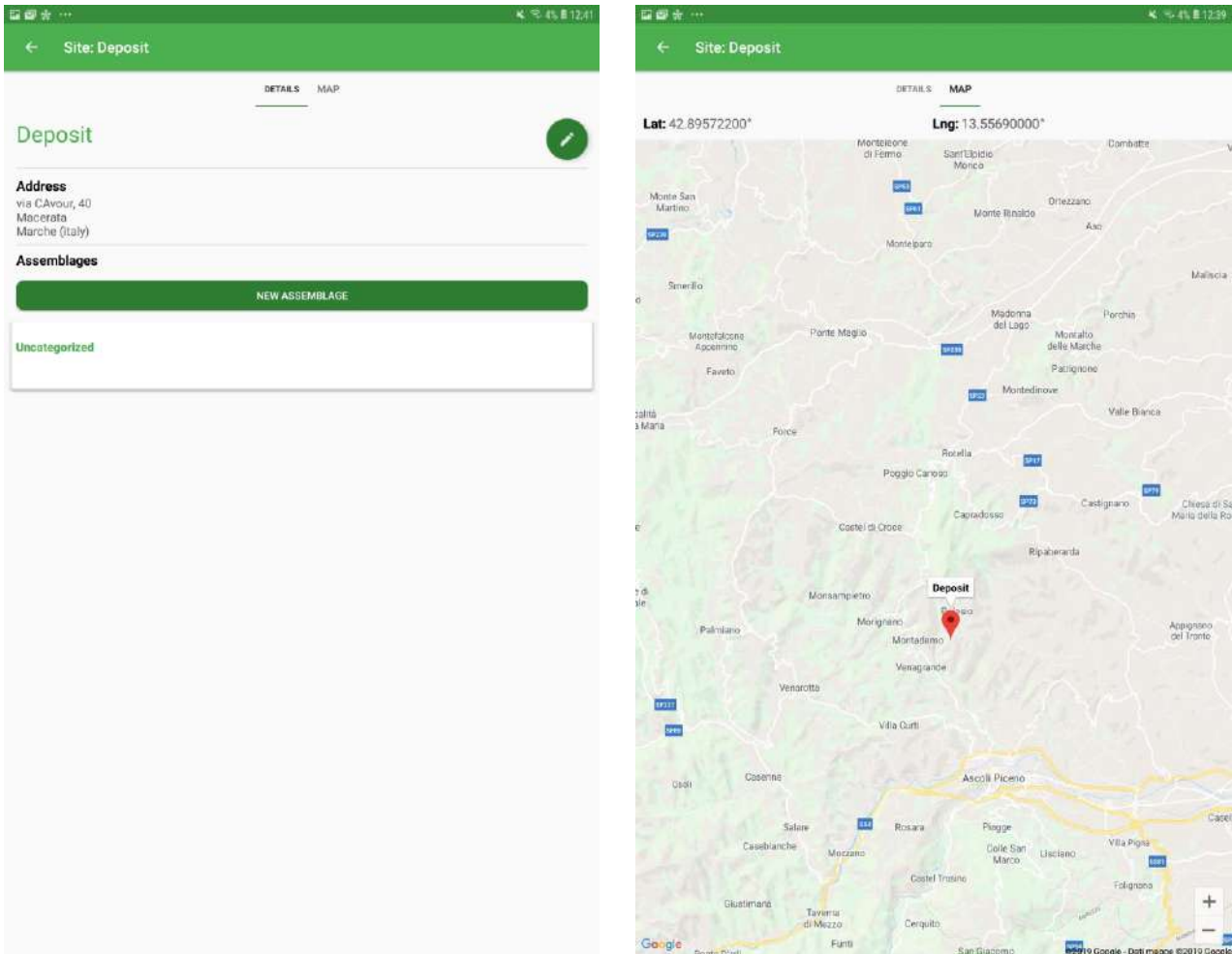
Fig.14 - The Site info: Details Tab (on the left) and Map Tab (on the right)

For fixing the geographical position of the site (right image above), it is enough to "drag" (tap on the marker, hold, move) the marker around. For an accurate positioning it is possible to use the zoom gestures to enlarge (zoom in) or restrict (zoom out) the map.

To edit the Site info (name and address) users would tap the edit button near the site name (see left image above) and access the editor window.

For each site, the user may define a list of assemblages containing the collected sherds. The only information required for the assemblage is the name. Tapping on an assemblage, the grid of the corresponding sherds will show.

3.5.2 Sherd

The collection of sherds composing an assemblage are presented as a grid showing the featured image of the sherd (the first added) and providing buttons to access the sherd details or remove the sherd (garbage basket). A new sherd may be added directly using the "+" button on the right bottom corner of the window.
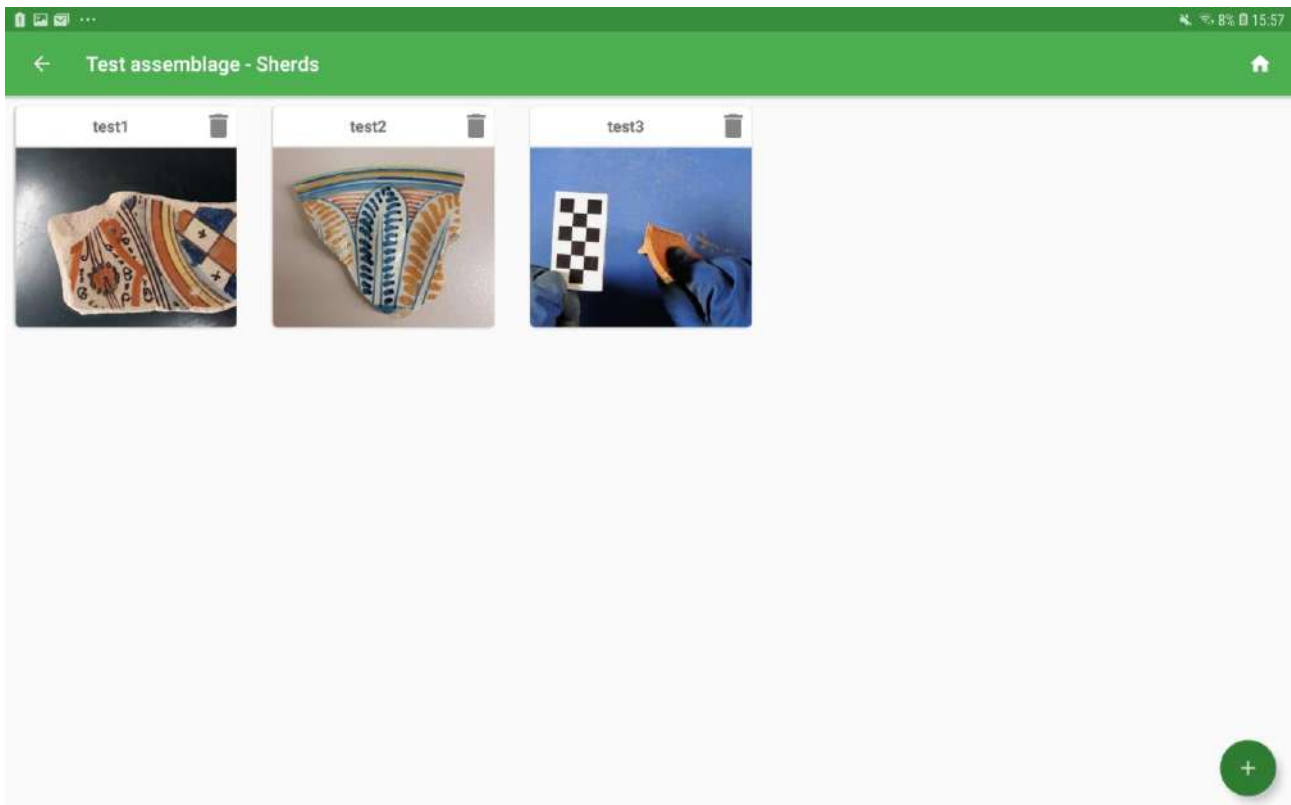
Fig.15 - Assemblage content: a grid of sherds

Entering the details of a sherd the user will be presented the following set of information:
- Name and general info
- Classification info
  - Type classification
  - Decoration classification
  - Stamp classification
- Depictions
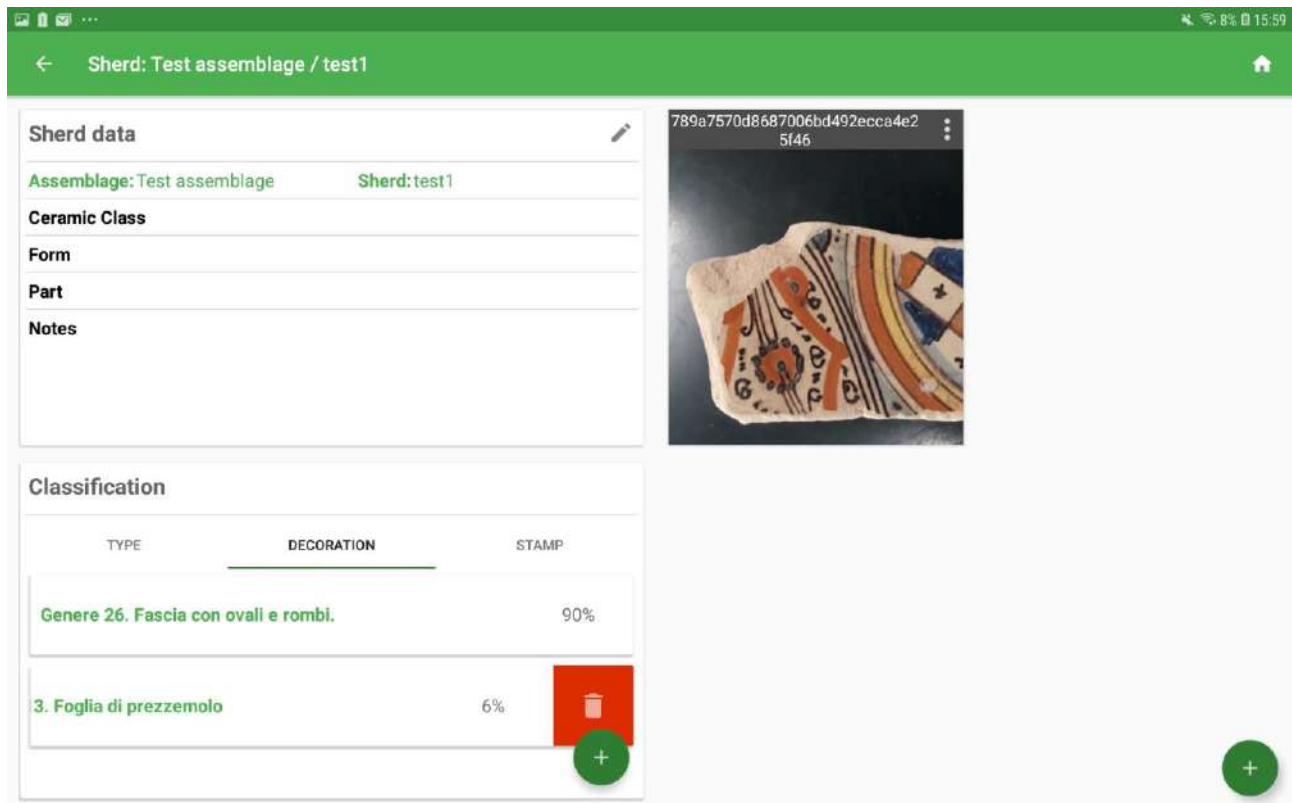
Fig.16 -The Sherd details view

The name and general information may be modified using the edit button (pen) near the sherd name. The classification info contains the list of classes (types, decoration and stamps) to which the sherd may belong to. The classification may be defined manually using the "+" button present in each tab or automatically using the classification tools. Using the swipe gesture on an element of the list is possible to remove the classification.

The depictions area contains the images collected for the specific sherd. In many cases, it may be useful to take a picture of the surface to get the decoration or the stamp or to take a picture emphasizing the fracture in order to classify the form. The automatic classification tools may be accessed using the context menu associated with each image. Selecting one of the tools, the corresponding interface will be launched assuming the starting image as the initial parameter. At the end of the recognition process, the classification info may be saved on the sherd using the save button. The "share" item allows sharing the image with other people through the sharing tools available on the device (i.e. mail, WhatsApp, etc.)
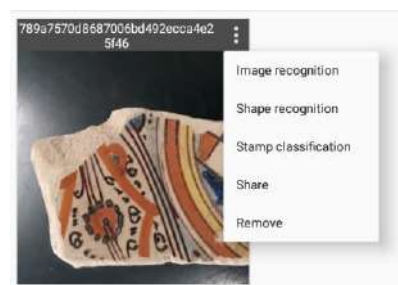
Fig.17 -The context menu associated with each

image

3.6 Classification tools

The ArchAIDE classification tools represent the real innovation brought by the project to the archaeology community. The classification is carried on by intelligent agents that try to infer the decoration class or the type class starting from an image of a sherd. Authenticated users may save the classification results together

with the image as a sherd. The classification of the stamps takes place comparing visually the sherd photo with the images of the entries in the stamp catalogue.

3.6.1 Decoration recognition

The automatic recognition of the decoration class of sherd starts from the image of the sherd that may be taken directly through the camera or from the galleries of the device. The process consists of the following steps:

- Step1: Select the image
- Step2: Modify the image using the manipulation tools
- Step3: Isolate the sherd in the image
- Step4: Evaluate the results
- Step5: Save the results (if the user is logged in and the results are good)
- Step6: Manually classify the image by visual comparison

Fig.18 - Step 1: image to be used by the recogniser

If the image needs to be adjusted, the user may use the tools available in the menu button (pen on brown background - see image below) for flipping (horizontally, vertically) rotating and cropping.
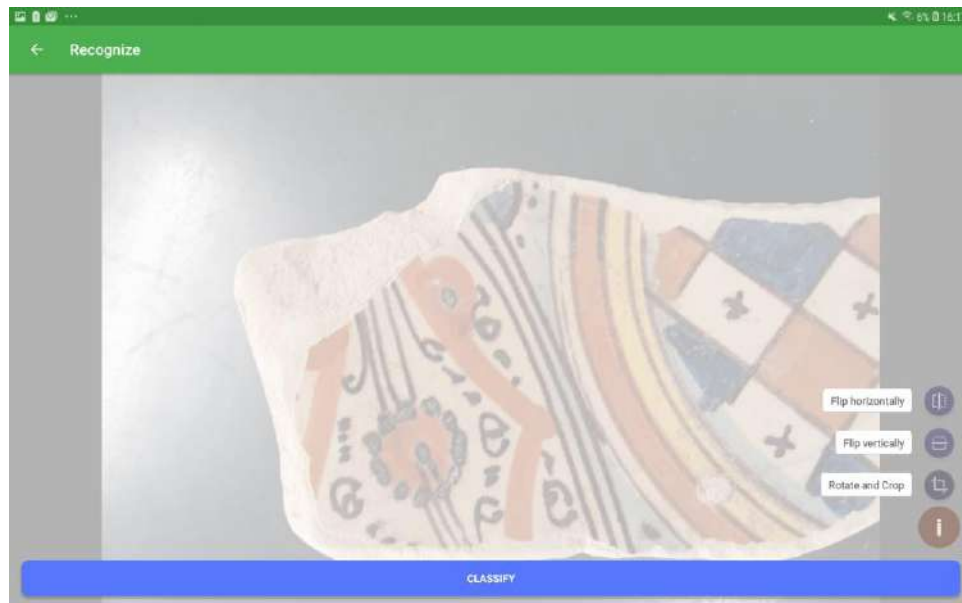
Fig.19 - Step 2: Fix the image using the image manipulation tools

Once the image is good, tapping on "Classify" the user moves to the second step: isolating the sherd (see image below). In this step, the goal is to obtain a clean image of the sherd where the background does not influence the recognition model. Usually, simply selecting the area containing the sherd will be enough but some time it may be necessary to remove the background with more advanced tools. The Step 2 interface provides an automatic background removal tool (the "Process" button), the identification rectangle (the most used) or a technique based on telling the GrabCut (see D6.3) algorithm which areas should remain (sherd) and which should be removed (background).
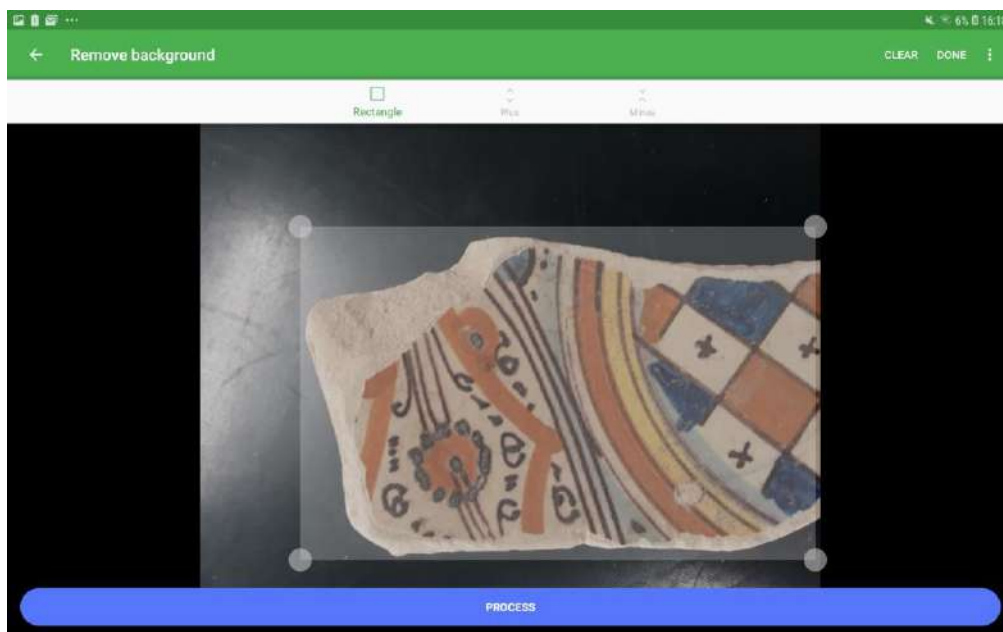
Fig.20 -Step 3: isolate the sherd (exclude background)

Tapping on the "Done" button (top right), the recogniser will be launched. This step requires Internet connectivity and takes the processed image and try to identify the decoration classes it belongs to. The recogniser returns 5 results ordered by a probability indicator (see the picture below).
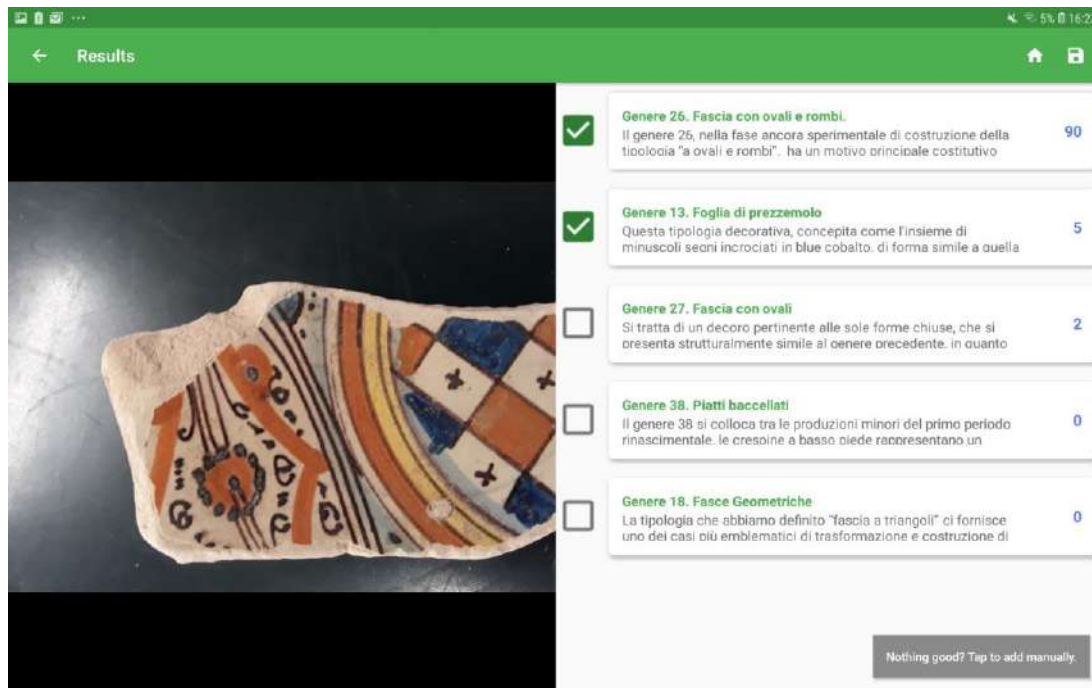
Fig.21 -Step 4: Evaluation of the results

If the user is satisfied by the results, may use the save button on the top right corner to save the results as a new sherd or inside an existing sherd.
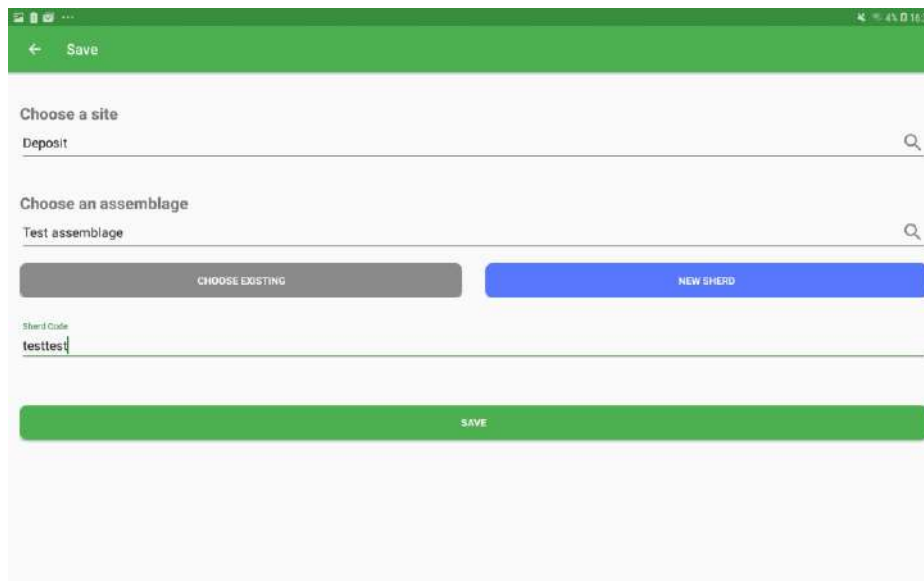
Fig.22 -Step 5: Save the results and the image as a new sherd or in an existing sherd
(only authenticated users)

Is important to note that only authenticated user can see the save button. Saving the results means telling the app in which site/assemblage the sherd should be saved and if we want to save it as a new sherd, which name assigns to it.

If the user is not satisfied by the automatically generated results may use the "**Nothing good? Tap to add manually**" button on the bottom right corner of the result window, to try a manual classification.
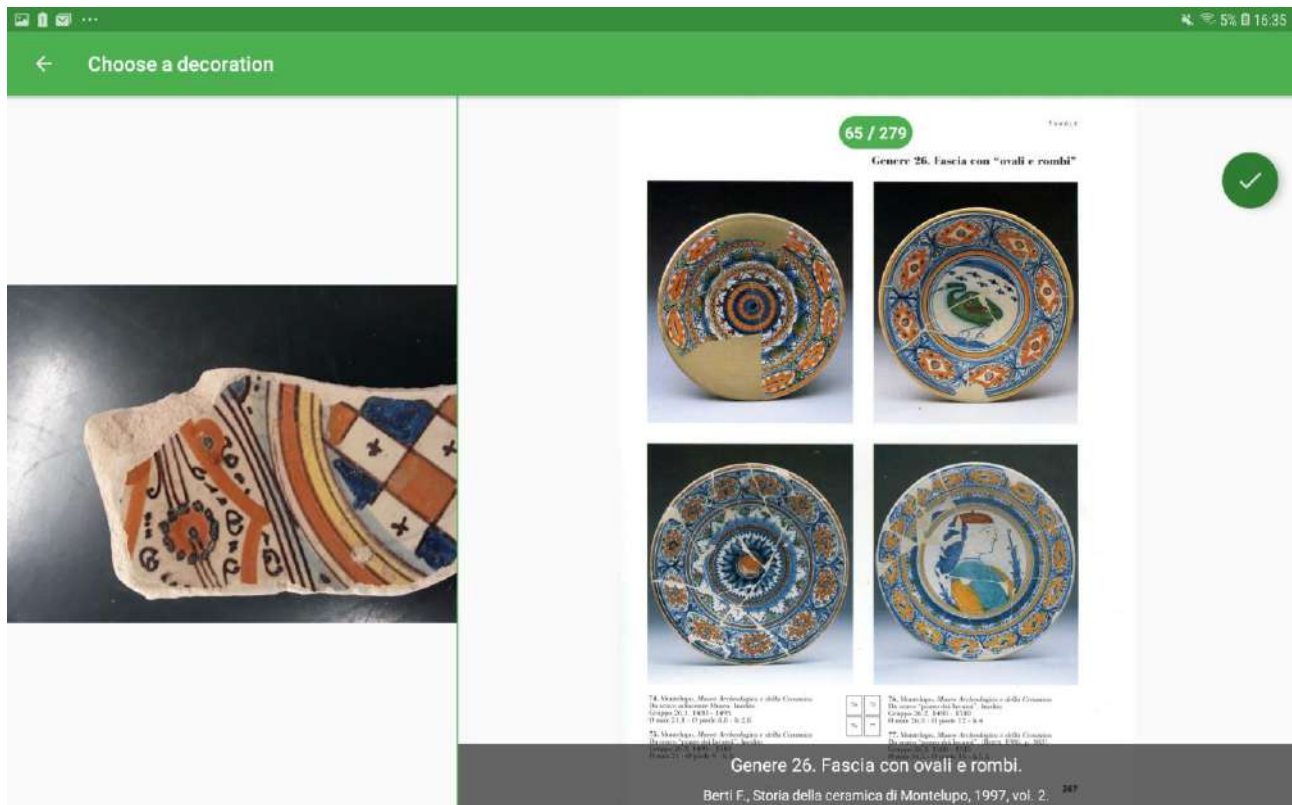
Fig.23 -Step 6: Manual classification by comparing the picture with catalogue pictures

Essentially the user is able to visually compare the real potsherd with the images available in the catalogue

(right-hand side in the image above) and when he/she finds a visual match, he/she uses the check button to save the selection. The images on the right may be changed swiping horizontally right-to-left (next image) or left-to-right (previous image).

3.6.2 Shape recognition

The shape recognition is based on the profile of a sherd fracture represented in SVG format (D6.3). The process starts with an image of the sherd focused on the fracture and provides tools to extract the scale factor, the external and the internal profile of the potsherds. The extracted data are sent to the API Server that composes the SVG file and sends it to the Shape Recognition Model for a prediction. The results are enriched with database information and sent back to the App.

A call to the recogniser will result in 5 possible ceramic types, each with a specific probability, that the user may evaluate and eventually select and save. The overall process consists of the following sequential steps:

- Step 1: Image selection and manipulation
- Step 2: Definition of the scale factor
- Step 3: Extraction of the external profile
- Step 4: Extraction of the internal profile
- Step 5: Evaluation of results
- Step 6: Manual classification (alternative)
- Step 7: Save the info in a sherd (for authenticated users)
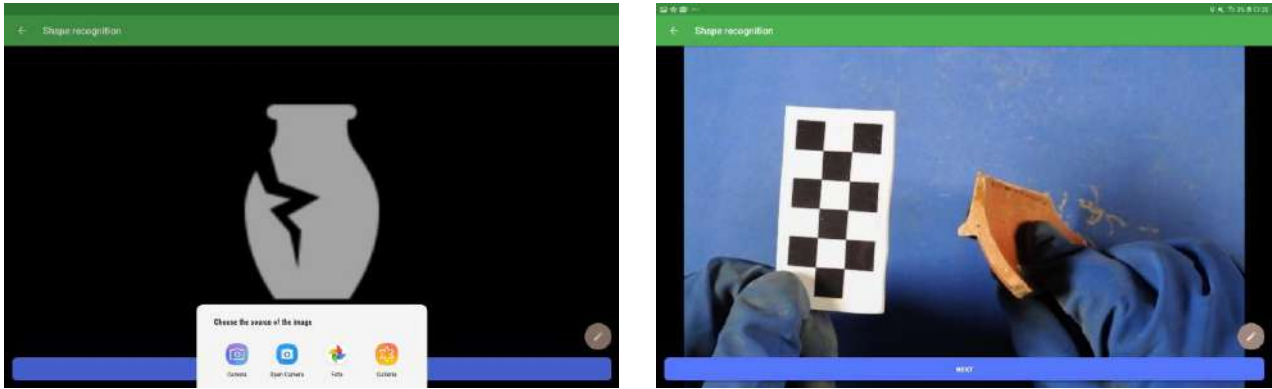
Fig.24 - Step 1: Image selection (on the left) and Image Selected (on the right)

The image to be used to sketch the profile may be selected from the device galleries (i.e. previously acquired images) or taken directly with the camera. Once selected, the image may be manipulated using the tools provided by the pen button on the right bottom corner of the screen.

The expected manipulations may be:

- **Flip horizontal**
  An important requirement is the in the final sketch the external profile must be on le left-hand side. The horizontal flipping of the image may be used at this purpose.
- **Rotation**
  The sherd fracture should be oriented in order to follow the real vessel orientation for improving the prediction probability.

It isn't necessary to make any other special manipulations of the image because it will **not** be used as input to the prediction.
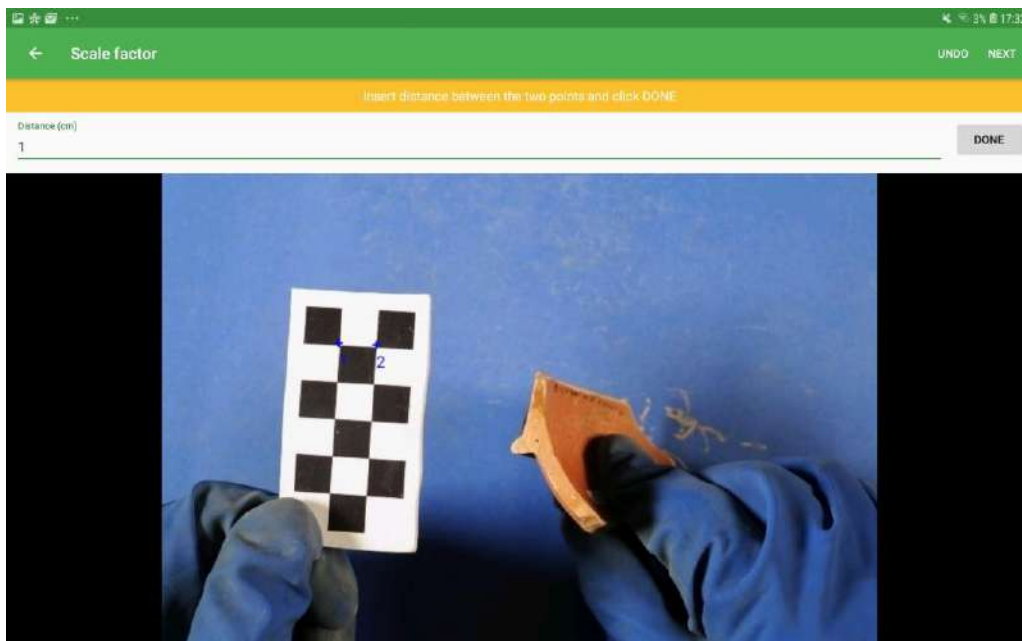
Fig.25 - Step 2: Definition of the scale factor

The definition of the scale factor is important in order to scale the image to the dimension of real vessels, helping the recognition tool in its search and retrieval task. To define the scale factor the user will be asked to select 2 points in the image and assert the distance in real life. For this reason, users must take pictures of the potsherds always with a ruler, that will have to be placed at the same level as the fractured profile.

Fig.26 - Step 3: Extraction of the external profile

Once the scale factor is defined the user may step forward to the extraction of the external profile. The process consists of using a finger to choose points along the external profile of the fracture. The density of the points depends on the complexity of the profile, it is important to capture all the discontinuities and curves of the profile. A smooth outer profile can be sketched with a few points. It is possible to clear the whole sketch or undo points sequentially.

Fig.27 - Step 4: Extraction of the internal profile

After the extraction of the external profile, the user should provide the internal one using the same technique.
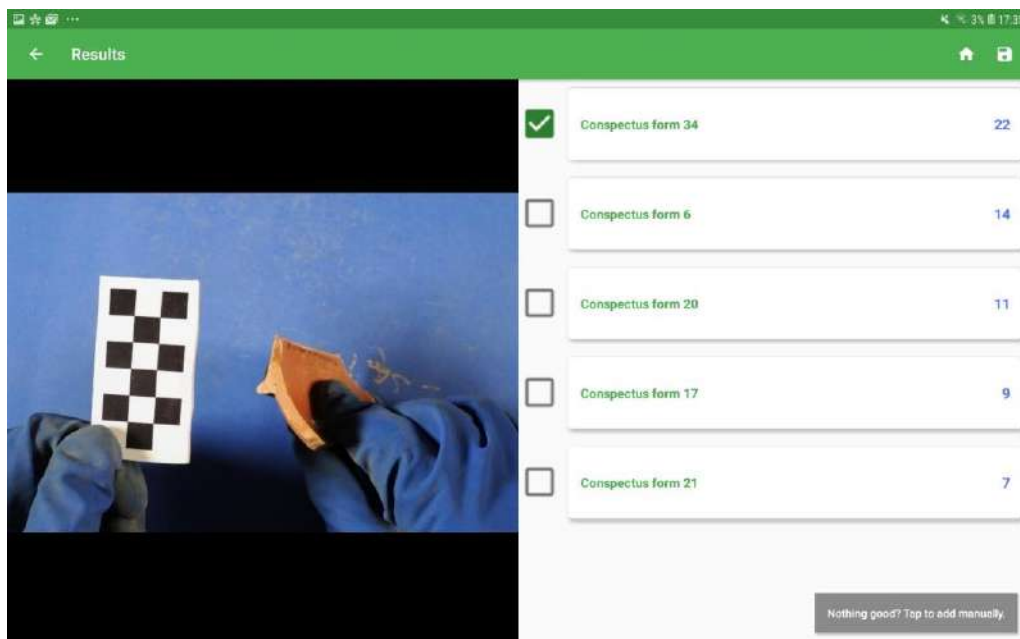
Fig.28 - Step 5: Evaluation of the results

In step 5, the user may evaluate the results of the prediction. Any prediction consists of 5 ceramic types with different probabilities. Is important to note that, as ceramic types are structured in classes and subclasses, the prediction engine tries to identify only the top level classes as discussed in D5.1. For example, the class "*Conspectus form 34*" (see image above) is the parent of "*Conspectus form 34.1*" and "*Conspectus form 34.2*" that differ one from the other of small bits that cannot be easily captured by the neural network but that are also difficult to distinguish by humans.
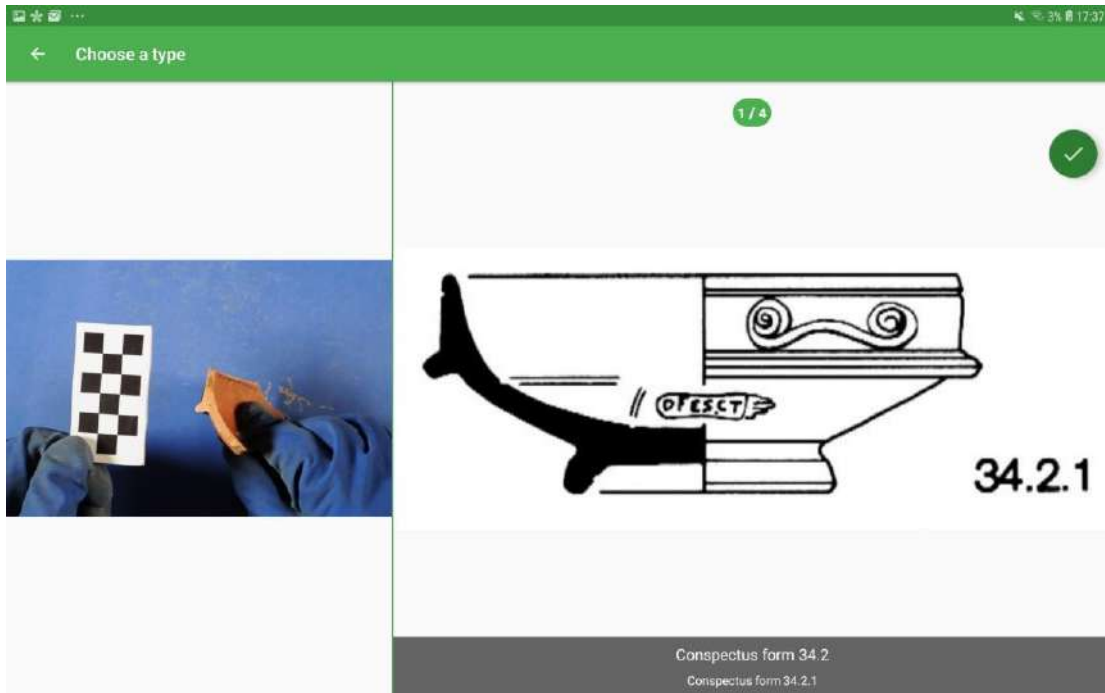
Fig.29 - Step 6: Manual classification by visual matching

As already explained for the decoration recognition, if the user isn't happy with the prediction may proceed manually tapping on the button "**Nothing good? Tap to add manually**" and enter the visual matching interface. In the case of shape recognition, the comparison is between the sherd image and the drawing associated with the ceramic types in the Reference Database (see picture above).

3.6.3 Stamp classification

The stamp classification cannot be done with the machine learning technologies as the image recognition is particularly difficult if images are not taken in specific light conditions and because the number of available images for training the neural network was too small. In any case, the classification may be done using the information that can be directly read by the user: the visually recognisable letters on the sherd.

As for the previous classification tools, the first step for stamp classification is the acquisition of the stamp image from a gallery or directly with the camera as shown in the picture below.
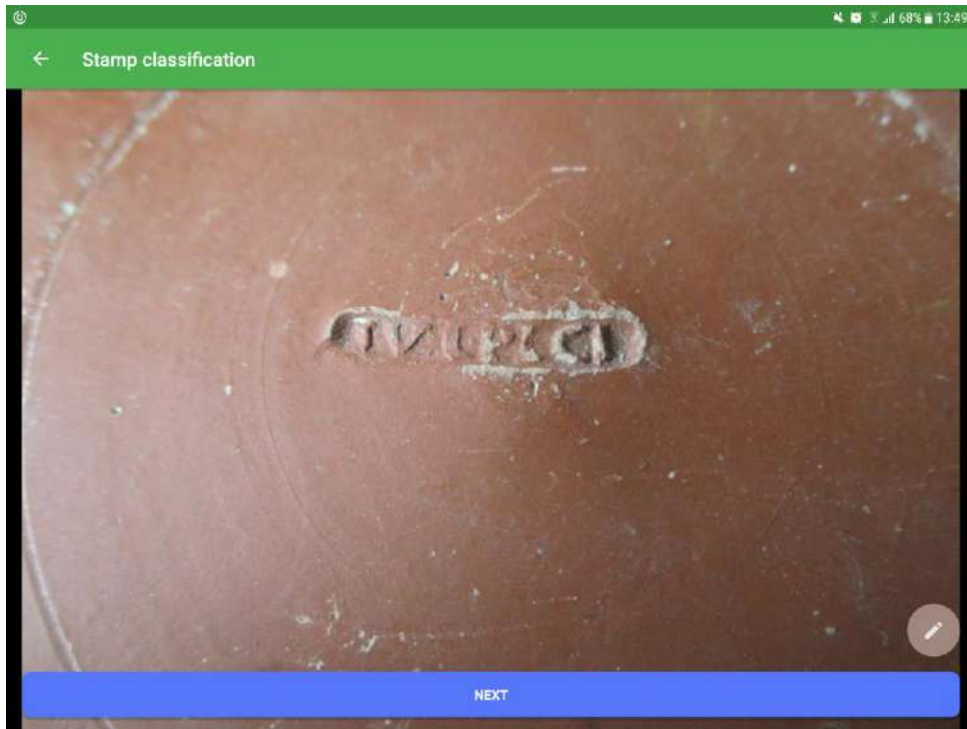
Fig.30 - Step 1: Image selection

Once the image is ready, the user would move to the search interface where he/she may use the search technique based on text patterns to isolate the stamps containing the letters that the user may visually identify in the image.
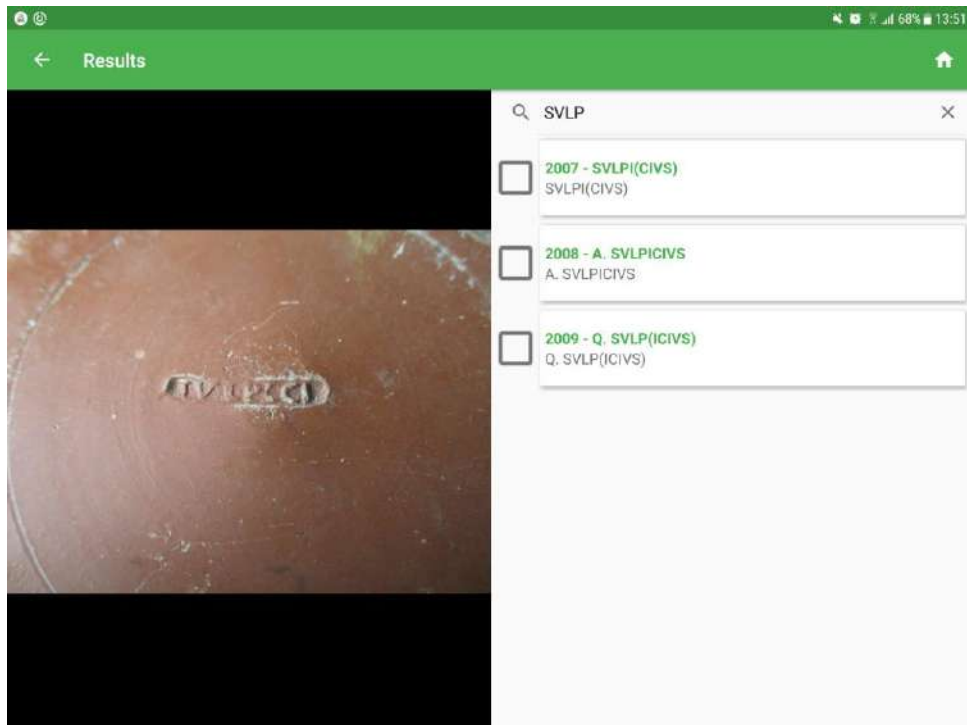
Fig.31 - Step 2: Search for the corresponding stamp

The search engine allows making searches including wildcard characters in order to match the text (for "Name stamps") contained in the stamp itself. The scenario is the one in which the archaeologist finds a sherd containing a stamp but only part of the name is readable or almost readable. To search a pattern like "ACCU …. R . S" (dots represents unreadable characters) the search engine allows to represent it as "ACCU%R_S" meaning "ACCU" followed by any character, then "R" followed by one character and finally "S". The searching for this pattern allows identifying the stamp "ACCU ILARUS". The wildcard characters that may be used in the keyword field are the following:

- **%** for zero, one, or multiple unknown characters
- **_** for a single unknown character

To activate the pattern search on the stamp text, the first character of the pattern should be **#**.

Examples of patterns may be the following:

- Typing "**#a%**" finds any values that start with "a"
- Typing "**#%a**" finds any values that end with "a"
- Typing "**#%or%**" finds any values that have "or" in any position
- Typing "**#_r%**" finds any values that have "r" in the second position
- Typing "**#a_%_%**" finds any values that start with "a" and are at least 3 characters in length
- Typing "**#a%o**" finds any values that start with "a" and ends with "o"

The search is case-insensitive.

4 ArchAIDE Desktop Application

The ArchAIDE Desktop Web Application is the result of Task 7.6 "*Implementation of the desktop front end*" carried on by Inera with the goal of integrating all the technologies and research results developed by the project in a single, powerful web tool kit for the archaeologists.

Accessing the ArchAIDE Desktop the final user will be provided with:

- **Web Content**
  Essentially a blog keeping the interested users up-to-date on the new features added to the ArchAIDE platform and the development plans.
- **Knowledge-base tools**
  Search & retrieval tools to access the type, decoration and stamp catalogues managed in the Reference Database.
- **Data visualisation tools**
  A collection of interactive tools for the visualisation of raw data and statistical data derived from the ArchAIDE database.
- **Search and classification tools**
  The collection of tools for automatic and supported classification of sherds: image recognition, shape recognition, stamp classification

The ArchAIDE Desktop will also be the place where archaeologists using the ArchAIDE App will be able to access their collected data (if registered). The site provides a **Sign-in** functionality that allows users to access their private data.

4.1 Architecture and technical infrastructure

The ArchAIDE Desktop web site is a hybrid application mixing web content and interactive tools. The implementation of the site requires a platform supporting Web Content Management and, at the same time, provides a robust and flexible extension mechanism to plug-in interactive tools. The best choice to satisfy this requirement is the use of open-source Portal Server technology: **Liferay 7.1**. Liferay Portal is an enterprise level, feature rich, portal server widely used all around the world to build medium/large web portals. In Liferay, a site is a collection of pages where each page is build composing and configuring user interface modules (Portlet). The platform comes with more than 60 portlets already available and supports an hot-deploy (i.e. no server restart) mechanism to add more custom portlet. Within the project, the Inera team developed specialized portlets for each tool (more than 10). In order to share the same user archive among the app, the reference database and the desktop web site it was implemented a single sign-on infrastructure based on CAS[6] (Central Authentication Server). Liferay Portal 7.1 ships with a set of embedded and ready to use SSO clients including CAS.
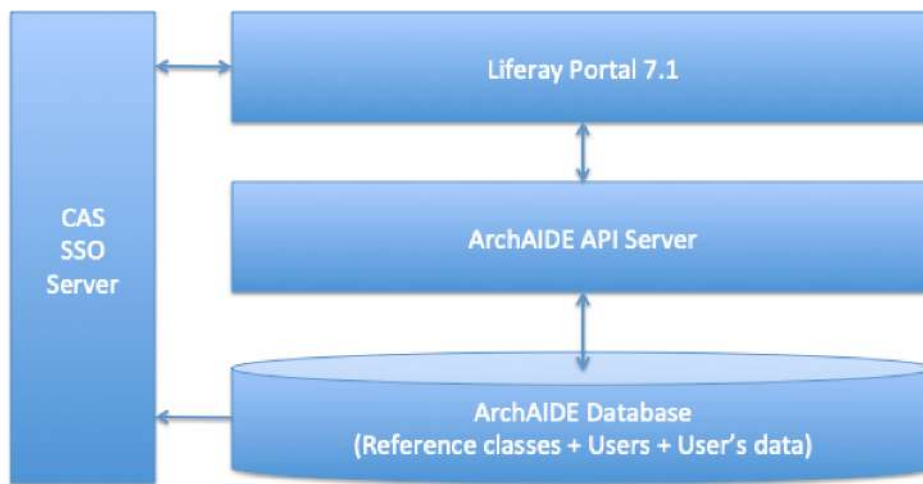
Fig.32 - ArchAIDE Desktop software architecture

The adoption of a powerful framework like Liferay Portal is particularly interesting in the light of the future and more service-oriented evolutions of ArchAIDE.

4.2 Content management

Liferay Portal 7.1 provides many of content assets that may be used to compose pages:
- **Web content**
  Static HTML content that can be added to any page (p.es. Privacy page). This type of content can be edited with a WYSIWYG editor or directly in HTML. Typical use is Descriptive text on top of pages, static text pages, etc.

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[6] https://www.apereo.org/projects/cas

- **Blogs**

  Full featured blog manager where the web content managers may add new posts as Featured image, Title, Sub-title, body, tags, etc.
- **Document & Media**

  A tool to collect and organize documents, images, movies, etc.
- **Wiki**

  A portlet allowing to build wiki sites. This type of content may be extremely useful to build Help sub-sites.
- **Polls**

  A small but useful portlet allowing to gather the opinion of the final users on the quality of services and the usability of the interfaces

The described assets may be managed only by known users with specific permissions and using the back-office tools. For each asset type Liferay provides a set of specialized management tools.

The first version of the site contains a blog with news about the evolutions of the site itself and improvements on the backend systems such as the Reference Database and the Deep-Learning models.
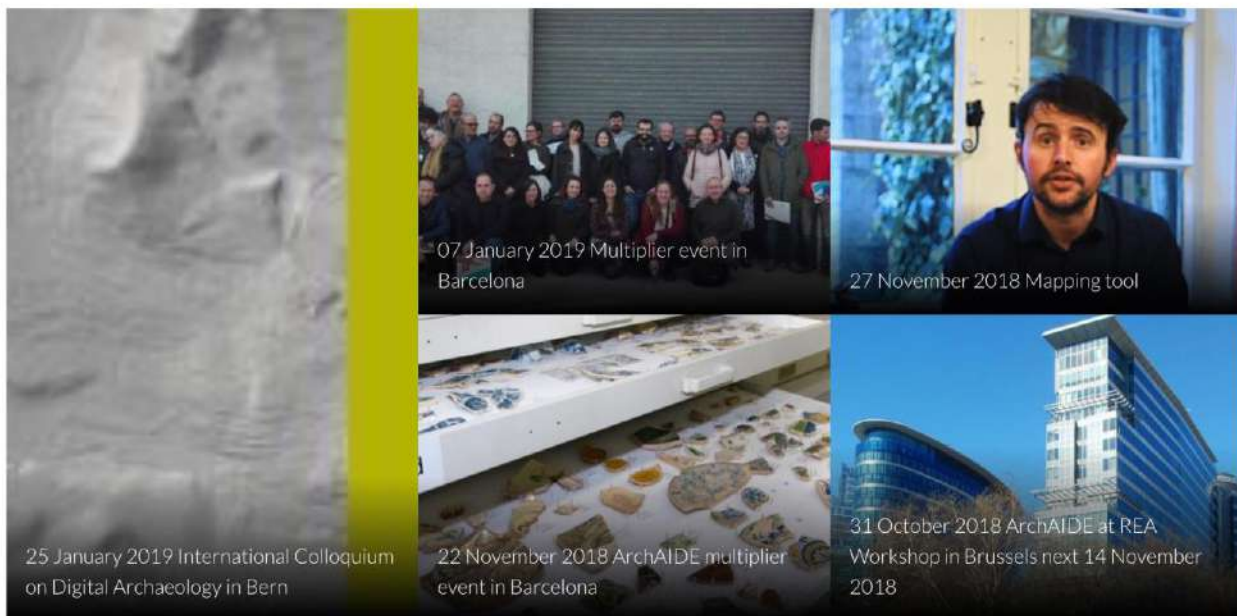
Fig.33 - ArchAIDE Desktop home-page blog

4.3 Knowledge-base tools

The ArchAIDE knowledge-base is a collection of search and retrieval tools that allows accessing the database of reference classes for types, decorations and stamps. The classes derive from online and paper catalogues that were used to populate what we call the "Reference Database".

The three tools have a similar structure with a search form followed by the list of search results. The search form presented to the users is a simple keyword search (see image below) where the keyword inserted by the user will be searched in all the text fields of the entity.
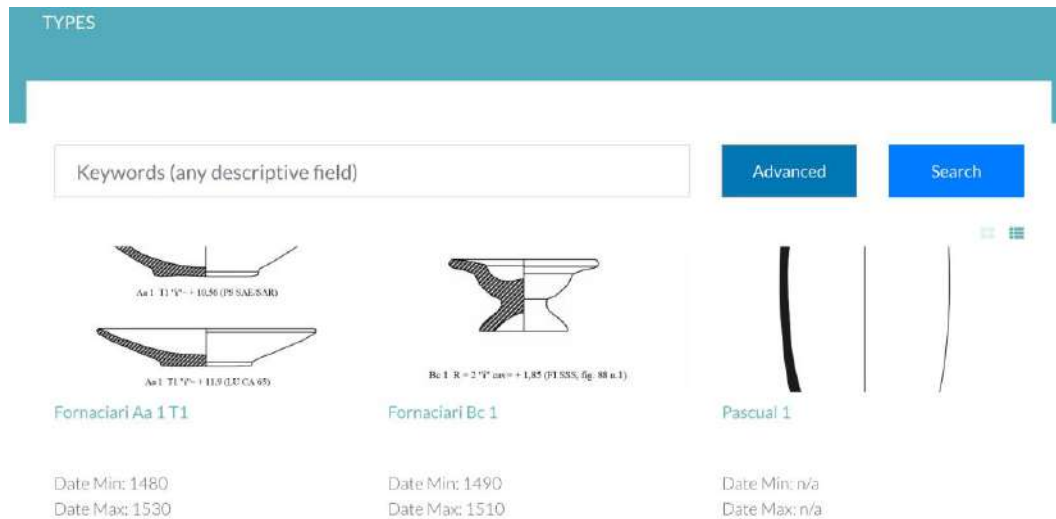
Fig.34 - Types: Simple search form

Clicking on the "Advanced" button (see next image) it will appear a complete form allowing to filter the results by all the relevant features of the specific entity.
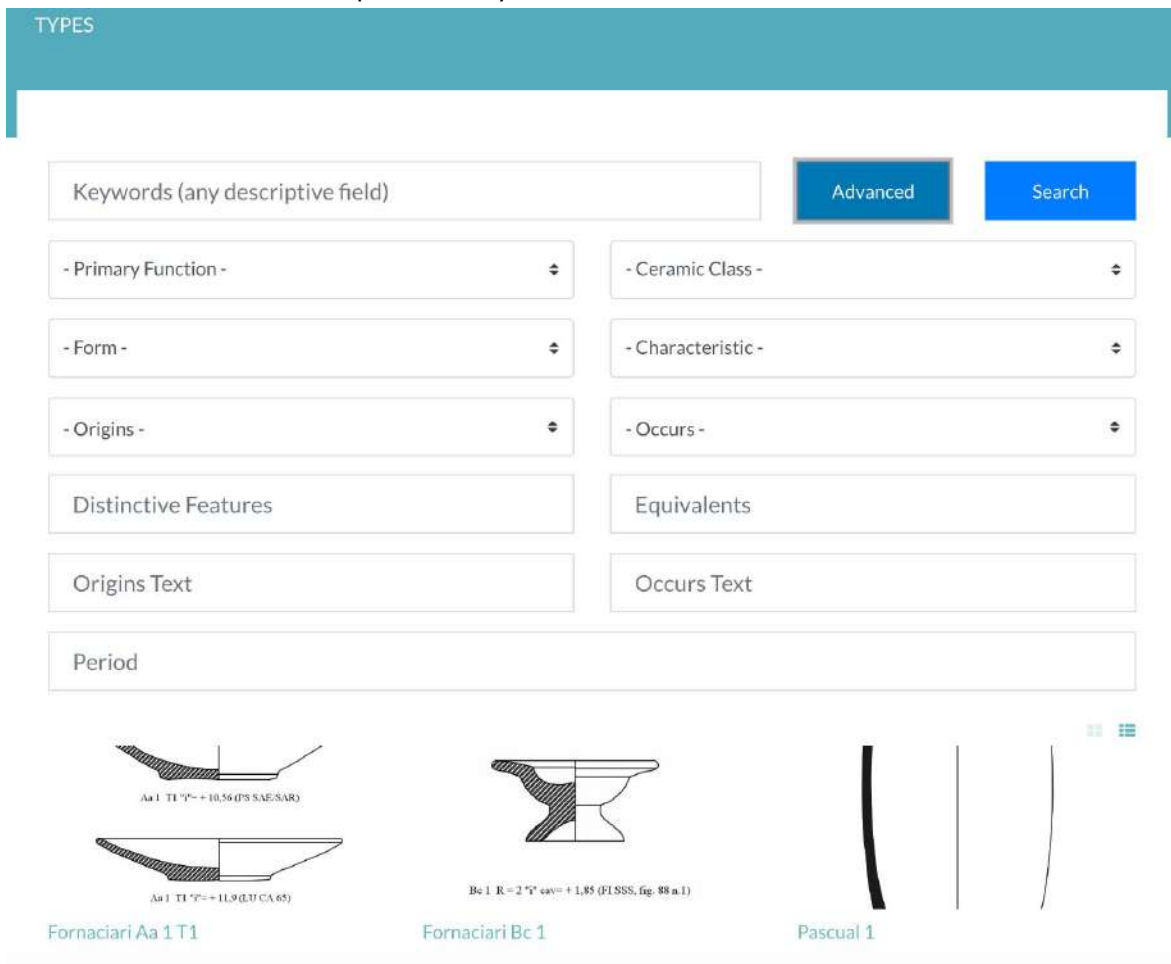

Fig.35 - Types: Advanced search form

The advanced search forms are specialized on the features of the corresponding entity. The above image shows the content of the advanced search form for the Type catalogue. In the next images are shown the advanced search for decorations and stamps.
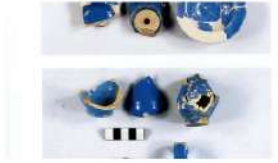
Fig.36 - Decorations: Advanced search

Fig.37 - Stamps: Advanced Search

Tapping on one of the results, the detailed view of the selected record will open. The view will be different for each entity and will show the whole content of the record and the relations involving it.

The best example is the detail view of a Type record shown in the following images, the detailed view for decoration and stamps follows the same approach.

The view of a type is composed of the following sections:

- **General info and 3D model/Main image**

  This section contains the type name, ceramic class, distinctive features and all the classification attributes (i.e. period, primary function, form, date range, etc.). If the type has one or more 3D models they will be shown immediately below the general inside a specialized interactive widget. If the 3D model is not defined it will be used the featured image (depiction) of the type.
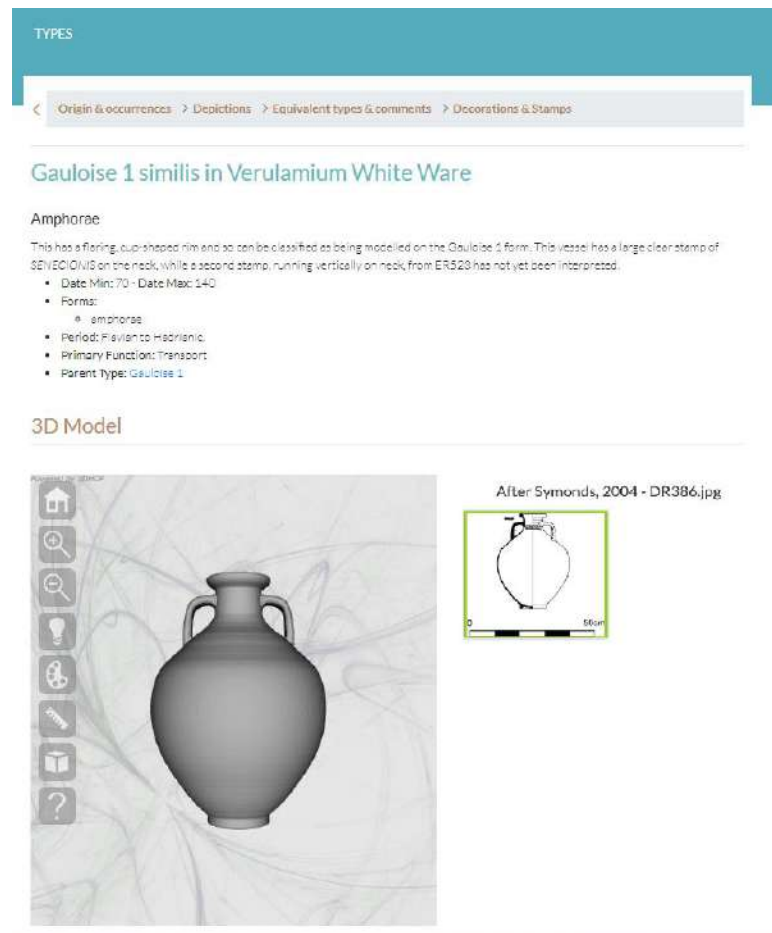

Fig.38 - The Detail View of a Type

- **Origins/Occurrences**

  The origins/occurrences section shows on a map the places where this ceramic type was produced and the places where it was found. Using the interactive tools provided by the map, it is possible to select origins or occurrences and zoom in/out.

Origin & occurrences

Various sites in and around London and Verulamium. Two neighbouring sites in London (30 Gresham Street, GST00; 2-12 Gresham Street, GSM97) have produced particularly large assemblages. Amphorae were produced at least two kiln sites: Brockley Hill, on the east side of Watling Street (1972 excavations. site A: Castle 1974), and Moorgate, on the northern margins of Londinium (Seeley forthcoming). Not so far recorded outside London or the kiln sites [check]. However, Verulamium Region pottery (especially mortaria) has a wide distribution in Britain and it is likely that examples will be recognised very soon.

Fig.39 - The Detailed View of a Type: particular of the distribution map

● **Depictions**

The grid of all multimedia object associated with the type. The grid may contain photos, drawings, thin sections, SVG files and 3D Models.
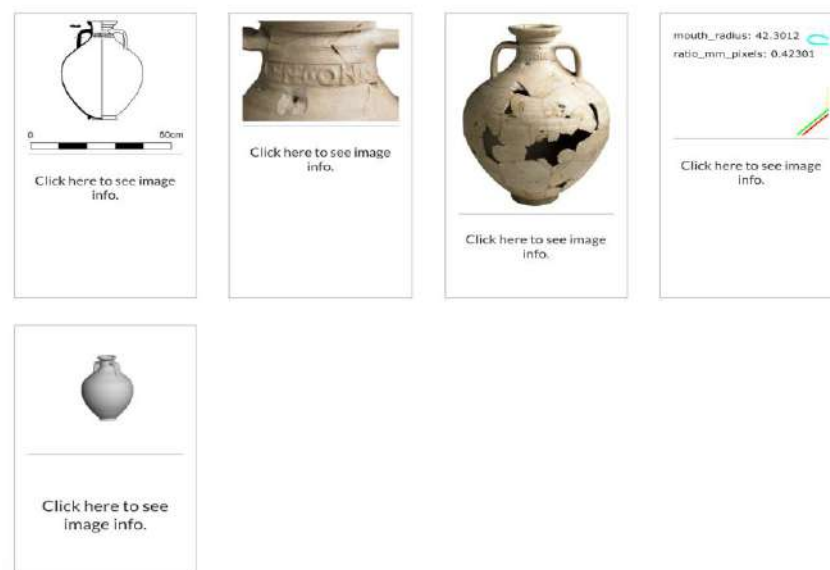

Fig.40 - The Detailed View of a Type: particular of the Depictions Section

- **Equivalences**

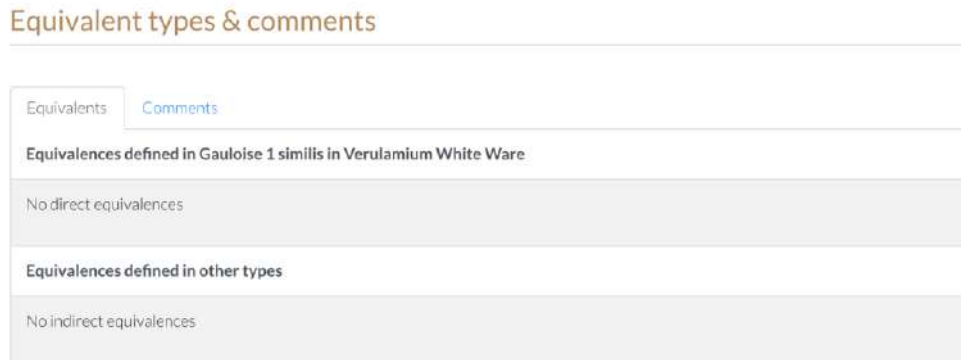 This section is dedicated to the equivalence relation for the type.

Fig.41 - The Detailed View of a Type: particular of the Equivalent Types & comments Section

- **Relations and references**

  A type class may be directly related to depictions and stamps. It means that a specific decoration or a specific stamp was found on the form we are inspecting. This area includes also the bibliographic references where it is possible to find more information about the type.

Fig.42 - The Detailed View of a Type: particular of the Relations and References Section

4.4 Data visualisation tools

The data visualisation area provides the internet user with tools to explore the raw data and statistics on the archaeological data collected by the project and described il the deliverable "**D7.1 Data analysis and visualisation component**". The data visualisation area is organized in a collection of pages corresponding to different interactive tools.

An example of a tool is the "Origins-Occurrences" page where it is possible to visualise all the places where it was produced or found specific pottery (based on workshop stamps) and, clicking on a place, visualise the source and destination through directed arches connecting places. Info about arches and places are shown directly on an info window available as a popup window on the marker itself.
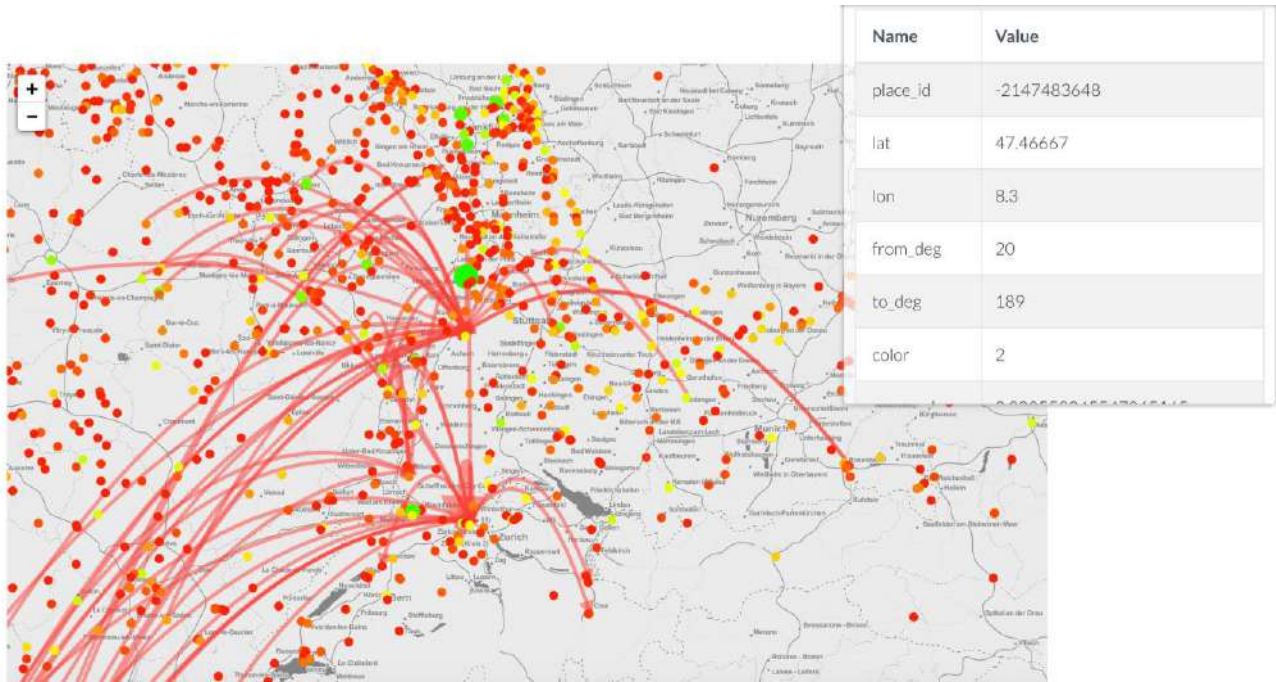
Fig.43 - Data visualisation: Origins-Occurrences

4.5 Search and classification tools

The main tools of the ArchAIDE Project are the artificial intelligence based recognisers which use images and shapes for classifying pottery sherds.

The automatic classification tools are the same as the one available on the mobile app:

- Image recognition
- Shape recognition
- Stamp classification

The main difference between the mobile app and the desktop website is in interactive tools used to manipulate images to be sent to the deep-learning models. The desktop website offers more opportunities in terms of the quality of the images used and precision in the selection, manipulation and profiling.
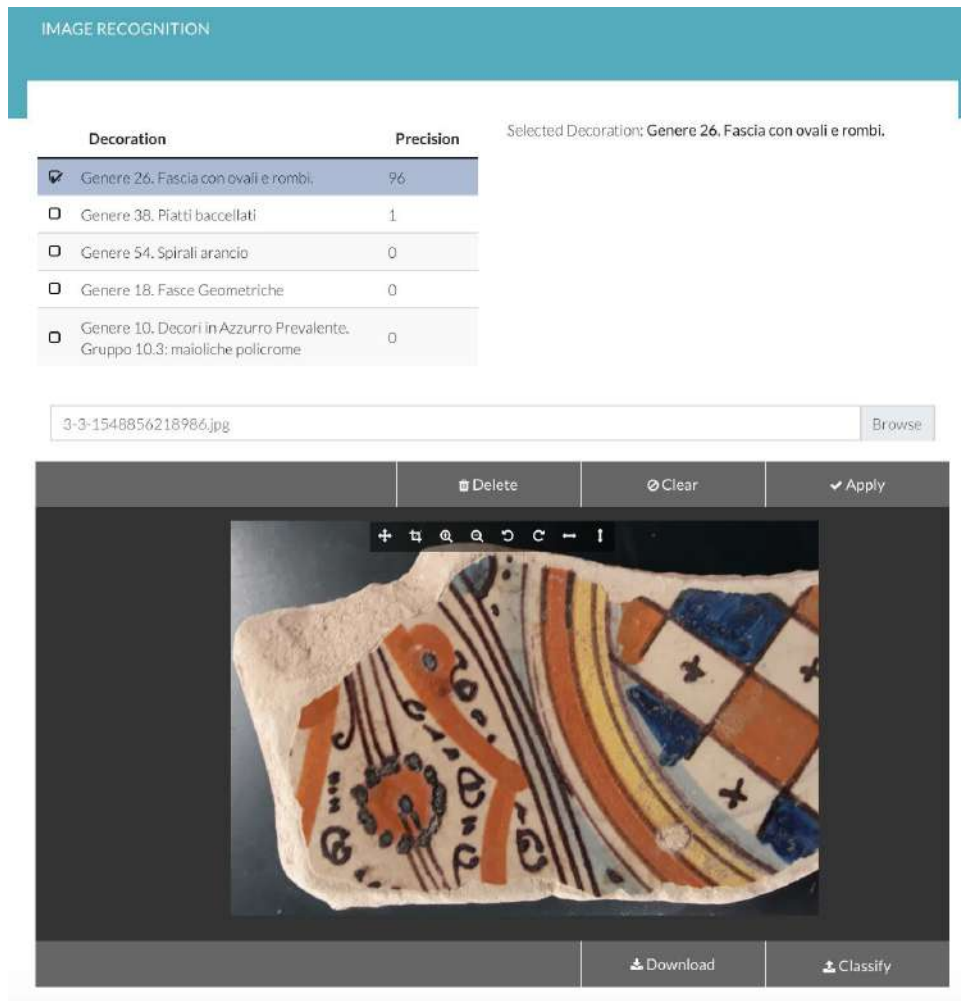
4.5.1 Image recognition

Fig.44 - Image recognition: Final result

The image recognition tool may be used to identify the decoration genre to which a give sherd belongs to (see image above). The user is required to select an image from the local filesystem, eventually apply transformations (crop, flip, rotate, etc.) and then push "Classify" button to ask the system to recognise the decoration. The results of classification (5 possible items) are shown as a selectable list where the user may select the preferred class if any.

Authenticated users have the opportunity to save the selected result as a new sherd or to save it in an existing sherd.
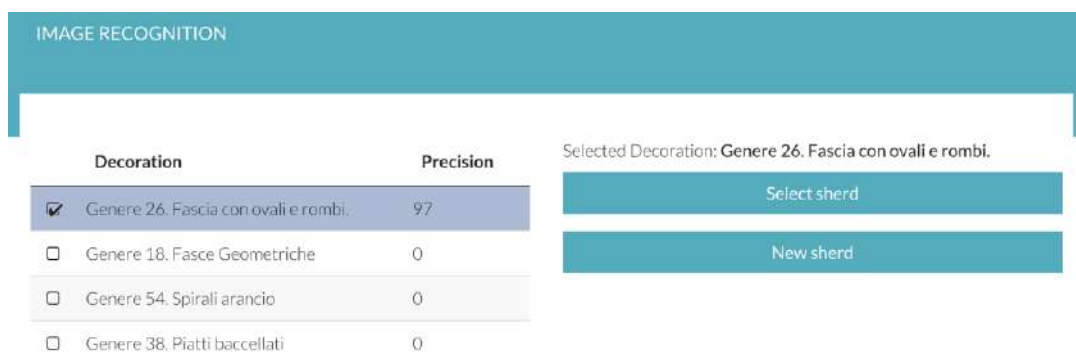

Fig.45 - Image recognition: Classification results for authenticated users

4.5.2 Shape Recognition

The shape recognition tool is a bit more complex as it requires more steps in the preparation of the data to be sent to the deep-learning model. In particular, the model requires, as input, an SVG file containing the scale factor, the external and the internal profile of the fracture. The interactive tool for shape recognition is a wizard guiding the user along the path from the initial image to the final classification request.

The first step is to upload an image using the upload field. On the uploaded image the user may apply transformations editing it. Typical transformations are:

- Flip horizontally: The external profile must always be on the left-hand side
- Rotate: to adjust the position of the sherd as it was on the vessel

The second step is the definition of the scale factor. The user will click in two points of the image and will insert a number representing the real-world distance between the points. The scale factor is essential to distinguish types with different dimensions and similar shape.

The third step is the drawing of the external profile. The user will draw a line selecting a sequence of points overlapping the external profile of the fracture. The fourth step consists in drawing the internal profile of the fracture using the same tool as the previous step.

Finally, the user will see a recap of the acquired information and will be enabled the "Classify" action.

During the above-described process, the user may always return back to a previous step to take a better measure or trace a better profile.
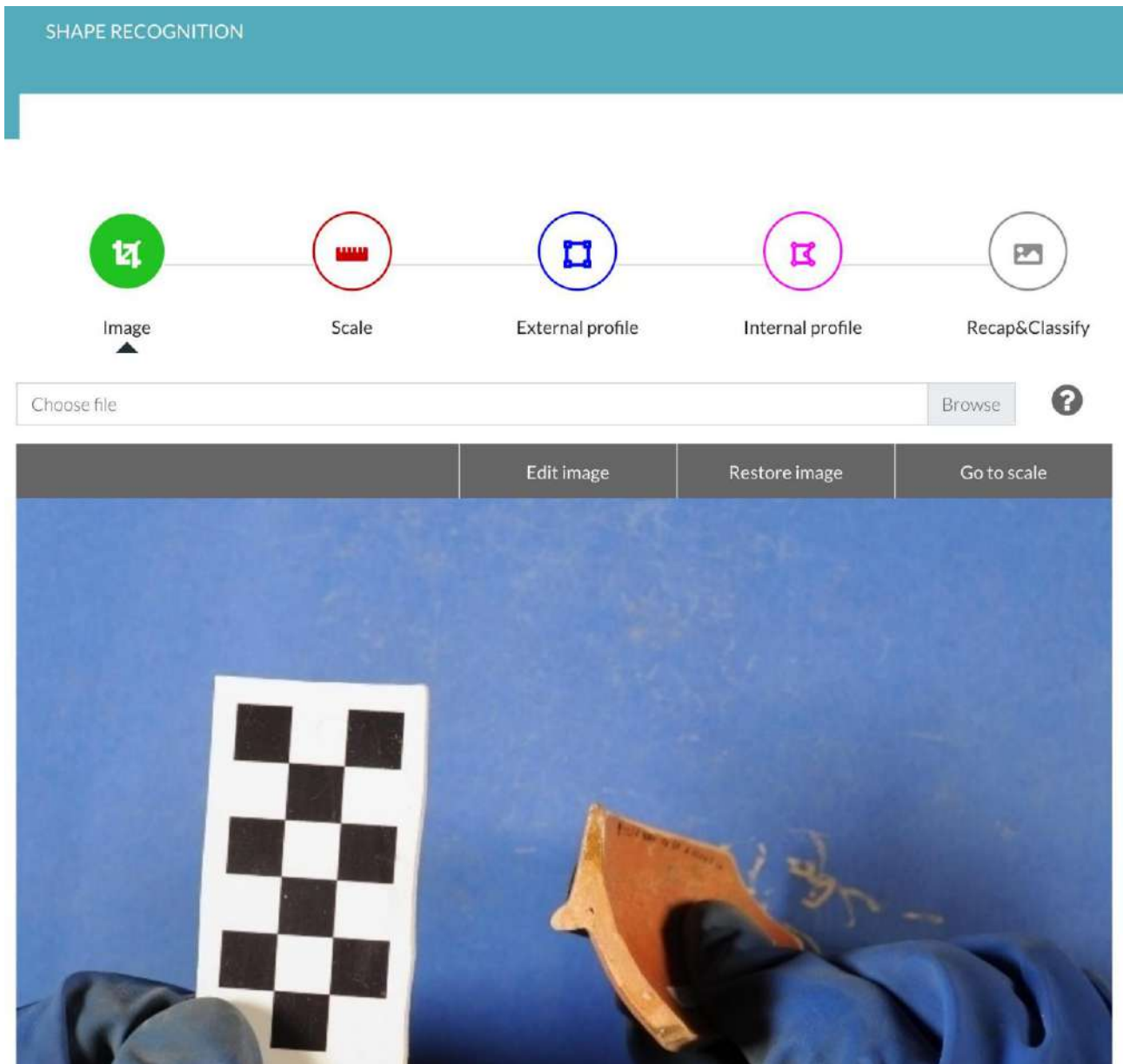
SHAPE RECOGNITION

Fig.46 - Shape recognition: Initial screen (with image loaded)

Fig.47 - From left to right: scale points, external profile extraction, internal profile extraction

The results of classification (5 possible classes) are shown as a selectable list where the user may select the preferred class if any. Authenticated users will have the opportunity to save the selected result as a new sherd or to save it in an existing sherd.

4.6 User account

Users that are already registered (via mobile app) to ArchAIDE may use the "Sign in" link, on the top menu of the site, to log in and be enabled to use the functionalities of authenticated users. In particular, known users may access to all the information collected through the app such as sites, assemblages and sherds.

5. Conclusion

Both the mobile and web applications are complete and compliant with the project goals but we consider them as the first step of the ArchAIDE adventure. The dissemination and multiplier events have shown a great interest from the end users and they hope for a good chance of success of the initiative in light of the project's exploitation strategy.

There are many features that can be improved or enhanced in order to obtain even more useful and incisive tools archaeologist's daily work. The next steps will be the following:

- Improve the quality of interaction for classification tools
- Integrate into the system the possibility, for the end user, to purchase catalogues protected by copyright
- Strengthen the tools for acquiring ceramic finds
- Strengthen the quantification and reporting tools