



HUMANOS: AN OPEN SOURCE NOMADIC SOFTWARE DATABASE FOR PHYSICAL ANTHROPOLOGY AND ARCHAEOLOGY

HumanOS: UN SOFTWARE NÓMADA DE BASE DE DATOS DE CÓDIGO ABIERTO PARA LA ANTROPOLOGÍA FÍSICA Y ARQUEOLOGÍA

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Highlights:

- We have developed a mobile application which allows "field anthropologists" to record burials inventories from archaeological excavations on site and in the laboratory, in an intuitive way.
- In addition to recording the skeleton, the application makes it possible to note the context of the discovery and to create fields of investigation according to its own research objectives.
- It allows data export in the form of text (automatic report) and/or tables for statistical uses.

Abstract:

With the democratization of computers, tablets and smartphones, the data acquisition and exploration on archaeological sites are changing significantly. The digitization of information allows a faster, more efficient and more standardized data recording that facilitates the synthesis work required by the discipline. Numerous database programmes are being developed in archaeology and physical anthropology, notably with targeted tools developed to meet specific needs. However, to the authors' knowledge, no efficient, free and open-source program for the recording of human bones in an archaeological context exists yet. In this paper, a mobile application for the intuitive recording of human bones from archaeological sites is described; this app, defined for the field and biological anthropologists, allows making an inventory of the burials from site to the laboratory from archaeological digs in an intuitive style. In addition to the recording of the skeleton, the application permits the recording of the discovery context. The application also gives significant freedom to the user, who can easily create research fields to their own research objectives. Finally, it permits exporting the information, either as text (automatic report) and/or as tables for statistical use. It is a modular, ergonomic and portable tool which meets researchers' requirements without needing an internet connection; it stores the recorded information in several formats (CSV, SVG, HTML and/or JSON), in a sustainable computer language, permitting complementary modules development. The system is implemented in the form of a free and open-source web application, programmed in JavaScript (available from <http://www.humanos.cnrs.fr/>) and supplied in the form of a simple ZIP file to decompress. The application does not require any special installation, as it opens by clicking on the executable *HumanOS.html* with any web browser, even without an Internet connection.

Keywords: physical anthropology, database searching, archaeological site, interoperability, open-source software, software development

Resumen:

La adquisición y exploración de los datos en los yacimientos arqueológicos están cambiando significativamente con la democratización de las computadoras, tabletas y teléfonos inteligentes. La digitalización de la información permite un registro más rápido, más eficiente y más estandarizado de los datos, que facilita el trabajo de síntesis que requiere la disciplina. Se están elaborando numerosos programas de bases de datos en arqueología y antropología física, en particular con instrumentos específicos desarrollados para satisfacer las necesidades concretas. Sin embargo, hasta donde sabemos los autores, no existe todavía ningún programa eficiente, gratuito y de código abierto que registre los huesos humanos en un contexto arqueológico. Aquí se describe una aplicación móvil dirigida a antropólogos de campo y biólogos, que permita el registro intuitivo de los huesos humanos en sitios arqueológicos. En un estilo intuitivo, esta aplicación permite hacer un inventario de los entierros desde el sitio hasta el laboratorio a partir de las excavaciones arqueológicas. Además del registro del esqueleto, la aplicación permite registrar el contexto del descubrimiento. La aplicación también da gran libertad al usuario, permitiéndole crear fácilmente campos de investigación de acuerdo con

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sus propios objetivos de investigación. Por último, realiza la exportación de la información como texto (informe automático) y/o tablas para uso estadístico. Es una herramienta modular, ergonómica y portátil, que se adapta a las exigencias de los investigadores, sin requerir conexión a Internet; almacena la información registrada en varios formatos (CSV, SVG, HTML y/o JSON), en un lenguaje informático sostenible para el desarrollo de módulos complementarios. El sistema se implementa en forma de una aplicación web libre y de código abierto, programada en JavaScript (disponible en <http://www.humanos.cnrs.fr/>), suministrada en forma de un simple archivo ZIP para descomprimir. La aplicación no exige ninguna instalación especial; se abre haciendo clic en el ejecutable *HumanOS.html* con cualquier navegador web, incluso sin conexión a Internet.

Palabras clave: antropología física, búsqueda en bases de datos, yacimiento arqueológico, interoperabilidad, software de código abierto, desarrollo de software

1. Introduction

The archaeological excavation of burials of the past results in the destruction of the grave itself by displacing the human bones from their sedimentary context. The operation, therefore, consists of recording and archiving the maximum amount of information on-site to allow us to understand the method how the corpse was deposited, funerary practices and to reread the information, if necessary in the laboratory (Duday et al., 1990; Groen et al., 2015; Knüsel & Robb, 2016). To accomplish this task, the archaeologists use context sheets, mainly using paper or computers which are badly adapted for site use (i.e. Courtaud, 1996; Brickley & McKinley, 2004; Gaultier, 2017). In the laboratory, the first step is often to re-record the information, which represents both a source of errors and an important amount of time and money. In any case, over the last ten years or so, the creation of real protocols from the academic world (Mays, 2010) has become institutionalized within society (Crane et al., 2019).

In archaeology, techniques used for data acquisition, have evolved considerably since the end of the last century because of the digital revolution. From the excavation book associated with drawings or engravings, some archaeologists today practice the site detection with satellite imagery (Baeye et al., 2016; Elfadaly & Lasaponara, 2019; Lin et al., 2014), ground-penetrating radar (GPR) (Conyers et al., 2019) or electrical resistivity tomography (ERT) (Bernardini et al., 2018), the 3D digitization of the existing (lidar, photogrammetry and Computed Tomography (CT) scan) (Davies et al., 2012; Leierer et al., 2019; Santos et al., 2017; Waagen, 2019) and hypothetical reconstruction (Ferrari & Quarta, 2019; Rua & Alvito, 2011; Themistocleous, 2017). Rescue archaeology generates a large volume of data that should be homogenized to promote their sharing and synthesis (Altschul et al., 2017; Kintigh et al., 2014). Since archaeological data can only be studied once in its primary form, it is essential to keep the information collected carefully and in a sustainable manner (Chaillou, 2003; Marshall et al., 2018). With the democratization of computers, tablets, smartphones, the data acquisition and exploration on archaeological sites is changing significantly (Albert et al., 2016; Barreau et al., 2013; Egharevba et al., 2019; Thieler et al., 2016). The digitization of information allows a faster, more efficient and standardized recording of data that facilitates the synthesis work required by the discipline. Many database programs are developing in archaeology (Herzlinger & Grosman, 2018; LeFebvre et al., 2019) and physical anthropology, either at the initiative of personal development or collaborative (Eve & Hunt, 2008; Feugère, 2011; Gailledrat, 2016), or still institutional (Cuy et al., 2017; Meghini et al., 2017). At the same time, targeted tools are also being developed to meet specific needs: sex determination (Brůžek et al., 2017), stature calculation (Chan, 2013), construction of stratigraphic

diagrams (Desachy, 2008) or for 3D visualizations of skeletons (Kepple et al., 1998; Proko, 2014; Sachau-Carcel, 2012). Thematic database programs also make it possible to compile a variety of data for medical purposes, such as forensics, to assess human variability (Jantz and Moore-Jansen, 2000). These databases are bibliographic (Adams, 2004; McEntyre & Lipman, 2001), pedagogical (Ackerman, 1998; Kappelman & Keane, 2011) or documentary (Bureau, 2019; Lewis & Griffin, 2011).

Despite this important selection, we have not found an efficient and simple answer to the recording of human bones in an archaeological context. As part of this continuity, computer scientists and an anthropologist have developed an application open source called *HumanOS* (freely downloadable at <http://www.humanos.cnrs.fr/>). The goal is to optimize the recording of human bones from archaeological sites, in the field and the laboratory. Initial incomplete versions were presented in 2016 (Colleter et al., 2015) and 2017 (Colleter & Barreau, 2017). These prototypes served as a basis for discussion with various anthropologists who encouraged us to develop a stable final version presented in this paper. It is a simple osteological data acquisition and management tool for treating large quantities of human skeletal remains, counting and locating them. A graphical user interface was first developed, allowing to add osteological elements dynamically and ergonomically with images of human skeletons (adult, child, baby). The application is intended to be free, open source, nomadic, intuitive and adapted to any device. It allows standardized file export (JSON and/or CSV) for easy data exchange. The ambition of our tool is to facilitate field registration to avoid re-entry of data and allow real-time archiving to prevent data loss (Habert and Huc, 2010).

Here, we will first describe the method used for the development of this application, evoking its genesis and specific structure. Then, we will discuss the result of this implementation by explaining the main features concerning the inputs and outputs. Before concluding, an important part will be dedicated to the discussion of the first feedbacks from the field to the laboratory, the benefits and future developments.

2. Materials and method

At the origins of this application, many reflections have made it possible to choose data and usage requirements that respond as pertinently as possible to the needs of the community of anthropologists. In this section, we will attempt to describe these aspects.

2.1. Genesis

Following the rescue excavation of the whole of a convent in Rennes (France) (Colleter et al., 2019, 2016; Le Cloirec, 2017), a local database has been developed in

Python and PostgreSQL to facilitate the registration and management of information. More than 800 burials had been excavated. On this occasion, interactive skeletons were developed to provide simplified information about the presence and the state of conservation of the bones. Information concerning funerary archaeology (position of bodies, containers and decomposition spaces) and the biology of subjects (sex, age at death, etc.) were added. A catalogue of tombs could thus be generated from the collected data. Although efficient, this application was not intuitive enough, nor ergonomic and required some prerequisites in computer science. This database did not allow for direct field recording. The archaeologists had to re-encode their data at the beginning of the laboratory study. Also, the development of HumanOS is the porting of this database in a simpler environment, for dissemination and easier use to ensure the sustainability of data accessibility, and field recording. So, several constraints have imposed themselves on the project. We wanted to create a modular tool according to the problematics of researchers, a tool which is ergonomic, portable, without the need for an internet connection, a tool which stores the recorded information under several formats, royalty-free and open source, in a sustainable computer language for the development of complementary modules.

The application is downloadable from <http://www.humanos.cnrs.fr> to install it, simply unzip the folder. The archive consists of a folder *sources*, containing the structure of the database, and a file *HumanOS.html* which allows the opening of the application in any web environment (Chrome, Firefox, Safari, etc.). Creating a shortcut from this file allows to open the application from the desktop of the computer. For better identification, the icon of the shortcut can be modified with *HumanOS-icone.ico* located in the folder *sources*.

2.2. Specific source code descriptions

The basic coding was done using JavaScript around the information in JSON. The skeleton, his close context (the grave) and the more global context (the archaeological site) are at the centre of the program (Fig. 1). From the archaeological operation, the different geographical areas can be recorded (cemetery, habitation, zones, grids, etc.), as can the methods of determination of the sex and the age of the deceased. The user is free to use the vocabulary of their choice, likewise, for the methods the most appropriated for their study (determination macroscopic, metric, genetic, etc.). According to what level we place on the burial or the skeleton, the information on the archaeology, the funerary rituals, the physical anthropological information and/or the geolocation are recorded. The bones are recorded in the form of tables, 166 bones for the adults, 327 for the children and 229 for the babies. The continuous (metric) and discontinuous information (discrete) can be recorded according to the user's needs. The rarest bones in archaeology are not coded in the database (such as the inner ear bones, the sesamoids, the hyoid bone, etc.). If the user wishes, they can be noted in box "commentaries". The 16 principle articulations are coded according to the same technique, the metric information (i.e. levels, weight, length, etc.) or discrete (i.e. presence or absence of pathologies, discrete traits, etc.) can easily be associated in the discontinuous information.

The recorded data concern sites, burials, skeletons and all related information. The only solution for working offline with a full web application is web storage, this is a mechanism for storing data in the Web browser (Takasu *et al.*, 2015). Unlike cookies, the storage limit is far larger and information is not automatically transmitted to a server. In this way, the JSON data are stored in local storage, when the user clicks the "Save" button.

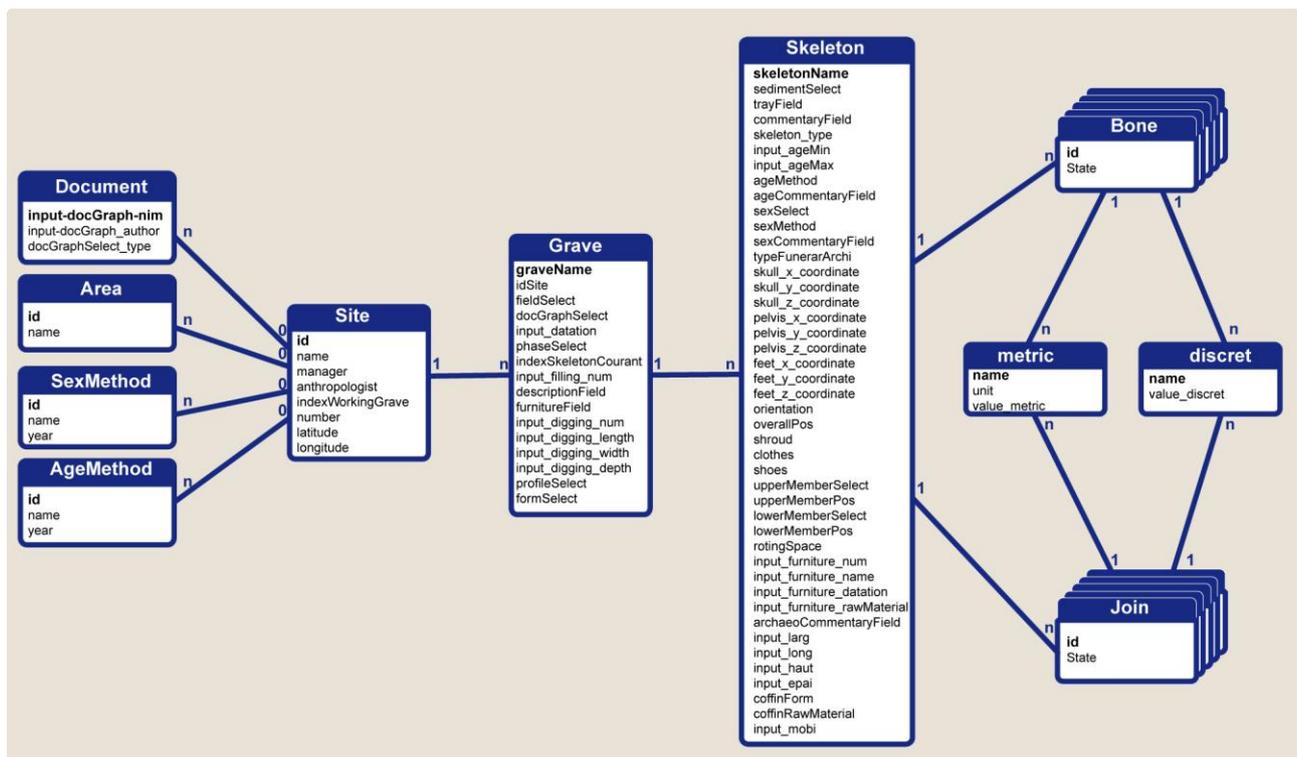


Figure 1: Scheme of dependencies of the main data structures and cardinalities.

Automatic recording of information in the local storage is fast, but with lots of data, it requires settings in the browser preferences. Indeed, according to web browsers, the storage limit in the cache is not the same. This limit can be a hindrance with the recording of too much data. Also, to allow more data to be stored in the HumanOS application, a procedure allows you to modify the characteristics, for the moment in Firefox. It is accessible in the "sources" folder called "increase_the_storage_limit_in_Firefox.pdf". Optimization of this recording is under study. A "sample.json" file is in the "HumanOS/sample" folder to test the application and its functionality.

We wanted to develop an application easy to modulate by the user. The list of choices can be freely created according to the problematic of the study of one or the others (field area, chronology, form and profile of the pits, funeral architecture, metric, discrete characters, etc.). The data format used by the application is JavaScript Object Notation (JSON). Whether stored in the local storage of the browser, imported or exported, their structure remains the same. As for many archaeological databases, one site contains elements, "here burials", which contain other elements, "here skeletons", etc. Each element is also associated with a set of parameters, explained in detail in the section concerning the application's behaviour. Finally, the languages are managed with a global variable, stored in the local storage, as well as with one JavaScript table by a language containing all the translations.

3. Results

With this stable version, we will explain the main inputs and outputs, designed by the field constraints and specificities of this discipline, mixing different human and natural sciences.

3.1. Features: Input

The application is simple to download and does not need a particular installation. It opens by clicking on the executable "HumanOS.html" with any web browser, even without an internet connection. A recording is carried out directly in the field in less than 15 minutes, avoiding re-encoding in the laboratory and thus drastically reducing sources of error. Thus, the data entered can be used directly for printing reports or any statistics. The first page of the application registers the archaeological operation: its name (address), an inventory number, its Global Navigation Satellite System (GNSS) coordinates, the name of the manager (site manager and anthropologist/archaeologist). The coordinates of the site are expressed in the sexagesimal system and are related to the topographic coordinates per skeleton, described later in the results section. It is from this page that the burials can be created ("New grave") (Fig. 2a). The second page records the information related to the grave: the digging and filling of pits can be given (Fig. 2b). A field can register a site sector. A date can be implemented with a box for text for absolute dating and a rolling menu for relative dating. Each burial can be considered as a set of skeletons and it is from the tab "new skeleton" that we access the details of the individual.

To the state of the skeleton, according to the age of death of the subject, different stages of maturity of the skeletons can be informed (Fig. 3). Bones can be saved faster using the "members" tool. The state of conservation indicates

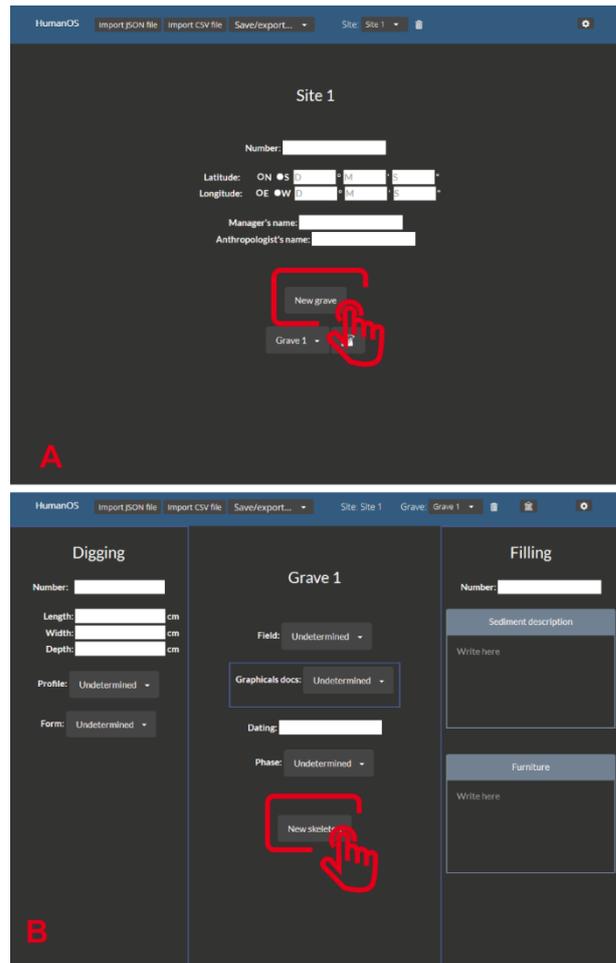


Figure 2: Home page of HumanOS: (a) Information concerning the archaeological site and access to the grave recording; (b) Access to the skeletons from the grave by clicking on "new skeletons".

only the fragmentation of the bone (less than 50%) or complete (more than 50%). Beyond a visual representation of the individual, the objective is to easily determine the minimum number of individuals. With the same principle, the connection of the joints can be indicated by the "joints" tool. The state of the articulated connections can then be recorded: connected, disconnected, loose connection or indeterminate. By default, the bones are absent and not connected. The place where the skeleton is stored is indicated in the "tray" box. A comment can be associated.

Then, from left to right, a series of tabs allows completing the skeleton's information (Fig. 4). The age at death, the sex and the methodology used can be specified. Each time, a space for commentaries is associated with detail, if necessary, the method used. These fields are identical for the adults or the infants even if the methods of analysis were different. The creation of a field for the sex of the infants is justified by the possibility of results of genetic studies or the development of new promising methods (Braga et al., 2019). Various information concerning funerary archaeology is grouped together. It concerns the funerary architecture, the position of the body, the method of deposit and archaeological material found. User-modifiable lists allow great flexibility and freedom to bring a maximum of possibilities. The individual can be geolocated. Three topographic coordinates per skeleton (head/pelvis/feet) can be filled in

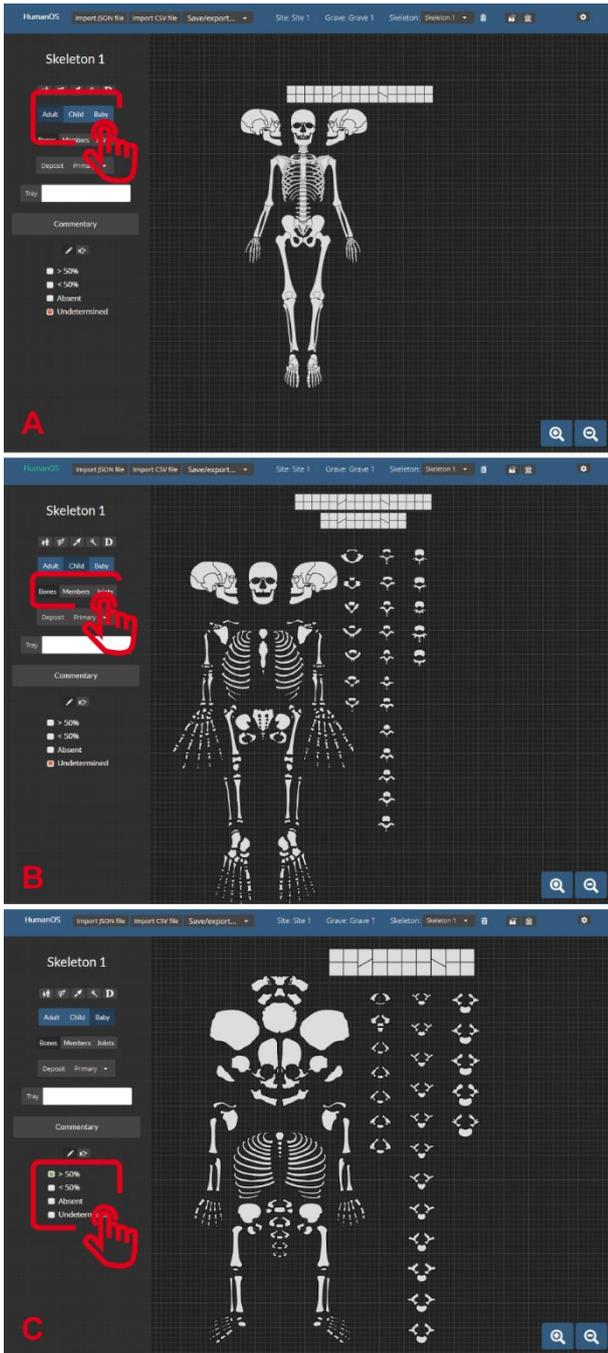


Figure 3: Interface of the recording of skeletons according to the age of death observed (adult, child, baby): (a) The maturity of the skeleton can easily be changed; (b) The user can choose to record at the level of bones, members or at articulations; (c) The state of conservation of the bones (complete, fragmented or indeterminate) or the connection anatomic (connection, loose connection, disconnected) can be recorded.

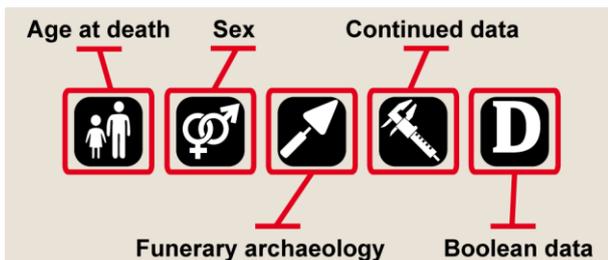


Figure 4: Menus proposed to describe the skeleton.

directly or imported in CSV according to a downloadable model in “Funeral archaeology/Download a form”. Once this form is completed, it can be imported via “import CSV file”, thus allowing to store this burial’s information, in the same environment, and easily shared later in JSON. Associated with bones and joints, the metric data are in the form of a table consisting of the bone/joint identifier, the label, the unit and the numeric value. The metric data allows a record of any continuous variable (i.e. the number of remains, length, weight, isotopes, etc.) that can be expressed in numbers or letters, if necessary. The default values for metrics are the right/left lengths of the humerus, femurs and shins in centimetres, but the values are easily modifiable. In the same way, the discrete types of bone/joint consist of the bone/joint identifier, the label and the type identifier. This window allows saving any boolean data type, such as discrete characters, but also pathological data, for example. A set of functions also allows switching between adult, child and baby skeletons, while keeping the bone selections, associated metrics and discrete types.

3.2. The export

Beyond the only ergonomic input of data, the HumanOS application allows then to export the files under different formats for (i) file sharing; (ii) the creation of an automatic report of the skeletons for archiving; (iii) statistical use in the environmental program adapted to the user (XLS, R, QGIS, etc.) and vectored images of the skeletons (Fig. 5). The durability of the recording, thanks to the different formats used (JSON, CSV, SVG and HTML) makes it possible to ensure a cross-search of data, available in several databases, and a follow-up of the development over time. Data exports in .JSON or .CSV make the tool interoperable, and so they are compatible with many operating systems like R for statistics, or QGIS for spatialized queries. The multiplication of the exporting formats proposed, allows for great suppleness in the use of the data. In addition to offering a clearer picture of the preserved skeleton, the bone selection allows an accurate inventory of bones for counting.

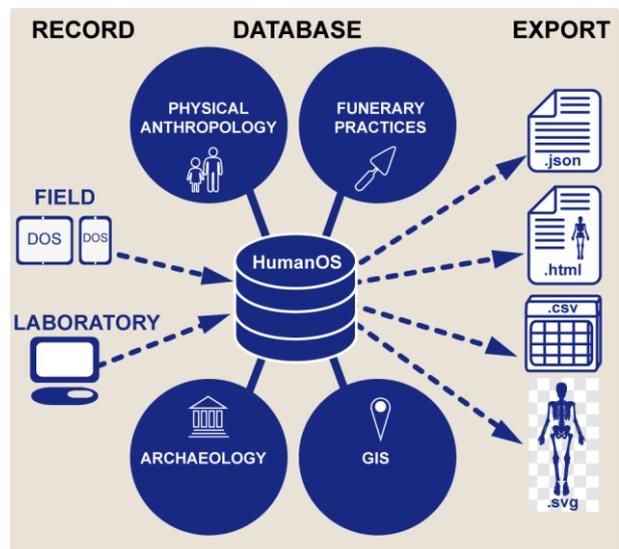


Figure 5: HumanOS functions and details of the different possibilities of exporting the data.

4. Discussion

In this section, we will discuss the first uses of the software, its potential capacity to make some practices in anthropology evolve, but also the improvements and evolutions that it would be interesting to implement.

4.1. The software in the field and laboratory context

The software was tested in the field on a Panasonic Toughbook CF-h2 tablet and then, in the laboratory on a laptop PC (Fig. 6). After a few punctual tests on archaeological diagnostics, the medieval cemetery of Olonne-sur-Mer (Vendée, France) studied in the field during an Inrap rescue excavation, between September to December 2018, appeared opportune for a full-scale trial. This site included 172 burials where 140 subjects were found in the primary position and 73 others in the secondary position, for a total of 213 subjects. Compared to the paper records used by the anthropologist on his previous missions, the digital recording systematized allows faster processing of data. However, the disadvantage of this organisation is the lack of precision for certain information, particularly concerning the funerary decomposition places. The numerous "commentary" boxes made it possible to specify their contents, but without an adequate keyboard in the field, only the checkboxes and the selection from the

drop-down lists were recorded. The generation of the sheets and their export allowed the printing progressively of the burials to archive the data before structures were removed. The printouts were used to note details that were reported on days of bad weather and at the beginning of the study in the database. The automatic writing of a report is a real time-saver for storing all the primary information of the burial. In addition to the application, photographs of each grave were also printed in the field to check their quality and directly annotate cross-checks, taphonomics, constraints, and other miscellaneous information. At this stage, the use of a printer seemed indispensable.

In the laboratory, with HumanOS software, the complete re-entry phase of field data was dispensed. Indeed, the information was directly recorded in the database from the archaeological excavation operation. This time was used in the study to complete the data and refine the descriptions. The first inventories were useful for sharing basic information with the various specialists mobilized for the operation (ceramologists and archaeologists). After washing and packaging the skeletons, the presence of bones was specified according to their conservation. The dental diagrams could be completed with precision. A count of the bone samples was made according to the maturation of the skeletons to calculate a minimum number of individuals (Fig. 7). Continuous and discontinuous data (discrete characters, buccodental



Figure 6: Using the application on site with a Panasonic Toughbook CF-h2. By zooming in on the adult skull, the user has access to record the cervical vertebrae.

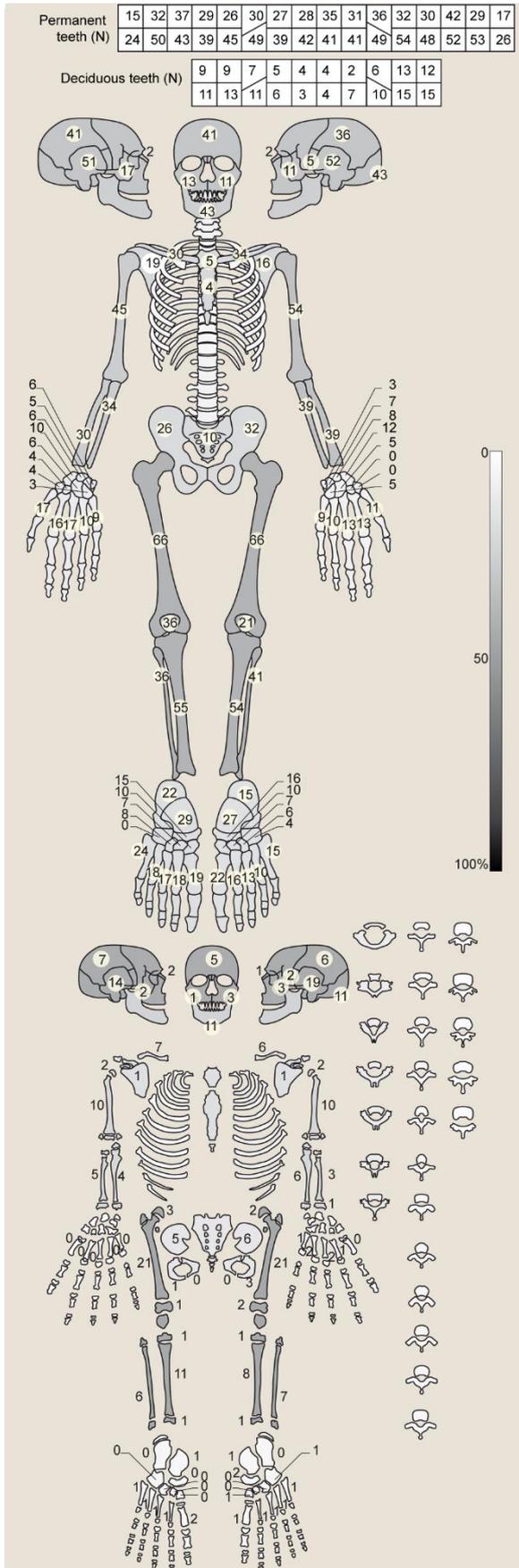


Figure 7: Number of bones (all dental, adult and immature skeletal data) preserved at more than half for all dental and adult bones. Grey indicates the proportional representation (%) of bones by joint segment, according to the age, at death, of the remains.

health status, palaeopathology) complete the field information. For skeletons, 6 metric values, 21 discrete traits, 4 enthesopathies, 4 pathological lesions (trauma, infectious, degenerative and other) and 3 dental damages (hypoplasia, caries, tartar) are inventoried. For each of these values, descriptive statistics could be produced.

File exchange between two workstations is possible and does not pose any problem, if the receiving workstation does not have common skeleton data. On the contrary case, a synchronization tool has been implemented ("parameter" tab), but it is currently limited to the level of burials, and overwrites the skeletons already started on the receiving device. The assumption of the online tool development discussed in the following implies a redevelopment of this synchronization tool. At this stage, we have decided to leave the application as it stands, because the first distribution of the data between colleagues is already possible.

4.2. Importance of application and benefits

According to the problematics posed by the anthropologist, the recording systems are different. The goal of creating databases is to impose and homogenize the entry of information while facilitating their management by sorting and searching according to multiple criteria. None of the databases is perfect but we have tried to give the freedom to the user to create their own listings. The lack of data is also recorded, as crucial information to obtain common denominators for information processing. The Database Management System allows to store, save, edit, sort and query information. The management of this database in open license environments (GNU GPL v3) makes it possible to ensure the durability of data accessibility, to couple them with tools, in particular, statistical computations and sometimes even automatic generation of documents (catalogue of tombs, skeleton conservation diagrams, ...). It is the user interface, as ergonomic as possible, that allows the use of these tools, without code or complex computer manipulation. Data recording is fast, flexible and easy to use.

HumanOS is designed as a minimal database for human remains. The application can both serve the fields of archaeology, physical anthropology and biological anthropology (Fig. 6). The primary inventory of the data makes it possible to dissociate the description (inventory of bones, biology, the position of the body, etc.), of the interpretation (the type of container, presence of a shroud, clothing, shoes, etc.). By being able to work on tactile support, the addition of information is intuitive and practical from the field to the laboratory. The installation is simple: just unzip the file and click on "*HumanOS.html*". The application then opens in any web browser. The application allows local work without internet connection and ensures the confidentiality of the data before publication. No need for login and therefore maintenance of the database.

4.3. Future developments

Following various initial feedback from anthropologists who have tested the application, it appears that there is a need for complementary data integration and interactions, around the data structure of the application, without the need to modify it in depth. First of all, at the level of burials, the capture of stratigraphic relationships, for example, modelled on the Desachy Stratified Model

(Desachy, 2008), would make it possible to have chronological relationships between tombs. Furthermore, the bones, are not detailed enough to record certain specific anatomical areas (i.e. the greater trochanter of the femur, iliac crest, etc.). Specifically, it would be interesting for the user to be able to break down the bones into three sections or add some landmarks, and to have access to the posterior view of the skeleton and a more detailed odontogram (Lugo et al., 2016) than in the current version. The current number of states of conservation is sufficient, but could be increased to at least 5 for specific needs. Associated with classical colourisation, it would even be relevant to be able to set colourable markers for conservation quantification on given points. Beyond the simple graphic representation of the skeleton, we have chosen to be able to use this information from a statistical point a view. At the moment, the commentary boxes can be used for particular descriptions. In order to enable a detailed recognition and annotation of the bones, it would need to integrate an interactive vectorized drawing tool (Morgan et al., 2018) allowing the user to note the specific anatomical areas. A large reflection about the integration of data concerning possible particular and/or disabling pathologies (Delattre, 2018) is also to be carried out in the near future.

Even if the numerous CSV export possibilities allow anthropologists/archaeologists to make statistical studies with their favourite spreadsheet, we are thinking of developing in the short term a query tool available directly in the application and allowing, in particular, the generation of heatmap density maps (Colleter, 2018). To add photographs of the excavation and the laboratory would be a real plus for the application. The problem of storage is related to the weight of the images, it seemed difficult to use both locally and file sharing between colleagues or in a publication (supplementary information). From these photos, the creation of 3D

models of the burials seems interesting to us. But the implementation of a local photo integration tool, especially for photogrammetric computation, remains rather heavy to realize, even if online modules have been developed recently (Locher et al., 2016; Nocerino et al., 2018). And if in the future we need to change our local approach and migrate some processing to a server in order to optimize the application, this module will have to be almost entirely recreated. This is why we wish to place this feature, not for the moment crucial, in developments with medium or long term perspectives. Back at the office, the automatic report generated by the application remains completely modifiable by any word processor, allowing it to be completed with photos.

We have also initiated the development of a module for the 3D vision of a site using the positions of the skulls, pelvis and feet (Fig. 8). The first technology chosen is the format extensible 3D (X3D) created by the Web3D Consortium. This makes it possible to do simple and quick tests on local web pages. The first feelings resulting from the visualisation of these first renderings are rather positive, in particular, because they make it possible to better observe the superimposed layers of burials. The long term objective is to be able to represent in 3D a maximum of information contained in JSON, geolocation or spatially deduced. When the first procedurally generated 3D cemetery visualisations of cemeteries seem relevant to us, we plan to develop a more sophisticated tool in WebGL. This could also be combined with the aforementioned photogrammetry protocols (Morgan et al., 2019; Tchérémissinoff & Seguin, 2019). Integrations in virtual reality are envisaged. We want to organize these complex developments in an open-source logic and within a larger community than our small team, in particular with a GitHub. Indeed, we need more developers to eventually switch from a standalone web application to a more classic client/server model, while keeping the existing web GUI.

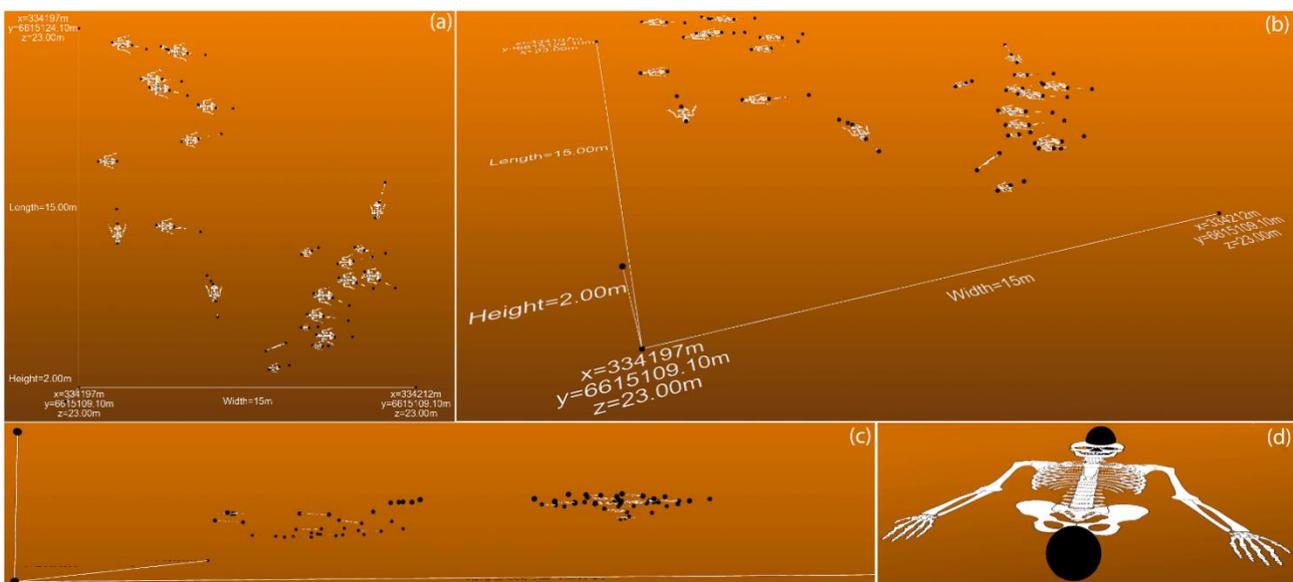


Figure 8: Views from a web browser of the module for 3D vision in the format web X3D of a site is being developed: (a) Top view showing the distribution of burials in (x,y) within an orthonormal system whose coordinate system are those of the GNNS points (herein Lambert 93 - EPSG:2154 / altitudes relative to the General levelling of France); (b) Front view perspective highlighting the width and height of the site; (c) Side view showing the overlay of layers; (d) View centred on the upper part of a skeleton, oriented by 2 spheres, whose centre coordinates correspond to GNNS points.

5. Conclusion

The search for large funeral ensembles, whatever the period considered, is interesting for the quantitative data, provided that it can be stored and queried easily. The available computer tools currently make it possible to process large volumes of statistical data, which are at the base of a potential renewal of knowledge. The archaeo-anthropological data collected are varied, they are as much interested in the funeral practices, in the restitution of the grave as in the biological characterization of the samples (sanitary state, food, genomics...). Currently, the challenge lies in the comparison of sites, and the constitution of increasingly important databases to write summaries and eventually encourage collaborative research to advance science and society.

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