Managing and Analyzing Archaeological Data with GIS: the Case of Place D'Youville, Montréal

Léon Robichaud
Département d'histoire
Université de Sherbrooke
Sherbrooke, Canada
leon.robichaud@usherbrooke.ca

Hendrik Van Gijseghem
Archéologie et histoire
Pointe-à-Callière, cité d'archéologie et d'histoire
Montréal, Canada
hendrikvg@pacmusee.qc.ca

Kim Petit
Laboratoire d'histoire et de patrimoine de Montréal
Université du Québec à Montréal
Montréal, Canada
petit.kim@uqam.ca

Joanne Burgess
Département d'histoire
Université du Québec à Montréal
Montréal, Canada
burgess.joanne@uqam.ca

***Abstract*— Large collections resulting from archaeological excavations can present challenges for data management and analysis. Confronted with a new collection of approximately half a million artifacts, the Pointe-à-Callière Museum partnered with the Université du Québec à Montréal and the Université de Sherbrooke to incorporate complex data visualization into a web-based GIS platform. This partnership has helped transfer expertise from universities to the institution and created a system which the Museum can use to better understand the site and its components.**

Keywords*— *archaeology, geographic information system, data, management, visualization, spatial analysis

I. Introduction

The 2017 archaeological excavation at place D'Youville in Montréal completed a series of campaigns which uncovered almost 50% of the area occupied by a large market building also used to house the Parliament of the Province of Canada from 1844 to 1849. The Pointe-à-Callière Museum has recovered approximately half a million artifacts from a grid of 124 suboperations to a depth of 5 meters, for a total of more than 800 lots. This collection presented new challenges for the institution in terms of data management, analysis and visualization. In this paper, we will present how the Museum partnered with the Université du Québec à Montréal and the Université de Sherbrooke to adapt spatial analysis tools to resolve these problems.

II. Historical Background

The particular history of place D'Youville has created favorable conditions for the preservation of archaeological data. Originally, it was the site of a small river (named Petite Rivière) which separated the fortified town from the pointe à Callière sector [1]. Once the fortifications were torn down in the early 19th century, part of the area was used for a live cattle market to alleviate overcrowding in the two old market squares. When the justices of the peace who managed municipal affairs chose to erect a new market in the early 1820s, the long and relatively wide open space of the river bed was selected as the building site. The Sainte-Anne market was designed as a large neoclassical two-storey building, 104-meters long and 18-meters wide, constructed from 1832 to 1834. The river was channeled underground to cool the basement storage areas and facilitate the evacuation of refuse. The channeled river was later integrated into the city's sewage system. In 1843, Montréal was chosen as the capital of the Province of Canada. The Sainte-Anne market, the largestbuilding available in the city, was adapted to temporarily house the assembly and the council. Following the adoption of a controversial bill by a reform government in 1849, a conservative mob attacked and set fire to the building. The remains were then leveled, and a new market was constructed on the same site in 1851. This building was itself demolished in 1901 and the space was converted into a public square, place D'Youville. A fire hall became the only above ground construction while other sections were left as public space or were converted into parking lots. An underground sewage collector prevented major redevelopments until 1989, when the old river and sewer were redirected into a new system. In the early 1990s, a large-scale development, which would have completely destroyed archaeological traces, was rejected as historians and archaeologists rediscovered the historical importance of the site.

III. The Challenge of a Large Collection

The nature of the destruction and limited subsequent disturbances has created near ideal conditions for the preservation of the archaeological record. Items which would not appear in normal historical sites can be found, and the dispersion of fragments related to a given object is relatively limited. Over the years, approximately 50% of the site has been uncovered by archaeologists. The density, distribution and number of artifacts would, however, require new tools to allow for the analysis and management of this important collection.

A. Previous Work

Given the character of the site, geographic information system (GIS) technologies were required for spatial analysis. The use of GIS in archaeology is growing and, while we are reminded that it does not provide all the answers [2], GIS is particularly suited to study spatial distribution [3], especially in areas with a high density of artifacts [4]. Other visualization tools were also needed but are not included in standard online GIS platforms. The OIC WEAVE project [5] offered a model for the integration of data, map and graphics, but the project is no longer active.

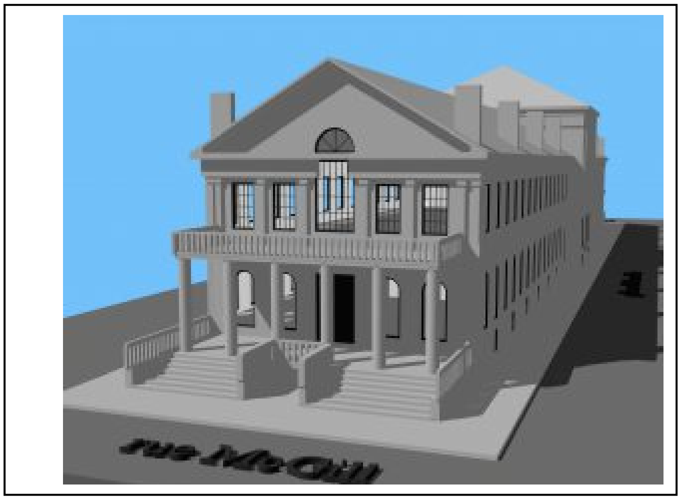
The place D'Youville archaeological site is managed by the Pointe-à-Callière Museum, Montréal's history and archaeology site. The institution itself was founded in 1992 (as part of the 350th anniversary of the founding of Montréal) when historical and archaeological interest in place D'Youville was growing. The Museum has had a long standing relationship with professor Joanne Burgess, director of the Laboratoire d'histoire et de patrimoine de Montréal (LHPM), based at the Université

The project was funded by the Social Science and Humanities Research Council of Canada, the Fonds de Recherche du Québec – Société et Culture, and the Ministère de l'Économie, de la Science et de l'Innovation du Québec.

978-1-7281-0292-4/18/$31.00 ©2018 IEEE

du Québec à Montréal (UQAM), and with professor Léon Robichaud, a historian and computing specialist from the Université de Sherbrooke (UdeS). As part of this collaboration, the LHPM team, which Robichaud co-directs, had modeled the market and Parliament buildings for Pointe-à-Callière in 2015 (Fig. 1).

Fig. 1. Model of the Sainte-Anne Market and Parliament building

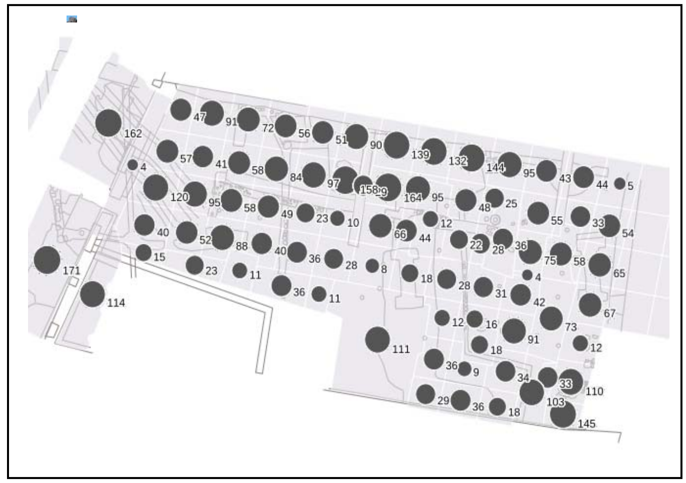


In 2015-2016, we experimented with a Unity3D interface to explore how selected objects were distributed on the site [6], but we also needed a system which could scale up to the massive number of artifacts which were expected to be recovered from place D'Youville in the excavation campaign scheduled for the following year. Simultaneously, in 2016, the excavation from a smaller nearby site (the original location of the first French settlement in Montréal) was completed and the data was available to test the capabilities of the LHPM's online GIS. The Système de Cartographie Historique de Montréal (SCHEMA) platform is developed by MapGears under the name eVouala [7] and offers a full GIS suite of tools. The system had already been customized to meet our requirements [8] and MapGears expressed interest in pursuing the development of its software to better answer the needs of the heritage and archaeological sectors.

B. *Pilot Project and Issues*

This test project provided us with 4683 artifacts. As is required for all archaeological excavations on the territory of the city of Montréal, data was entered in a FileMaker Pro flat file database using a structure defined by the city's archaeological heritage service. The data was exported to a spreadsheet to facilitate its integration into the GIS platform. Location data was defined as the suboperation from which each artifact was recovered (the square on the grid and the stratigraphic level). New fields were added to collapse the large number of artifact types into broader categories. The digitized grid surveyed on the ground was imported into our GIS platform and the first map showed the number of artifacts per suboperation (Fig. 2). Filters allowed us to map material or function, but two main problems remained. The granularity of the location data created the first obstacle. For each item, the location was the one-meter square lot and its strata, not its exact coordinates. Using the centroid, all points were superimposed, which meant that we could only visualize the distribution of all types of artifacts, or of one selected type at a time. Random distribution inside the polygon could have given the false impression of a precise location, and we did not want to correct a visualization problem while creating a perception problem.

Fig. 2. Overview of the distribution of artifacts, pilot project



Another issue was that we were limited to a plan visualization. The system did not allow for a cross-sectional view of the site with the distribution of artifacts by strata. We did not pursue development on this track because the strata had not been digitized and only existed as sketches. The challenge was to integrate graphical visualization tools to display a matrix that would represent an abstraction of artifact distribution both in plan and cross-section views.

C. *Funding the Development*

Existing components of our systems had been developed through a Social Science and Humanities Council of Canada (SSHRC) partnership research grant and a Fonds de recherche du Québec, Culture et Société (FRQSC) research team grant. New funding was required to integrate the tools and provide the types of visualizations needed for this project. The Passeport Innovation program of the Ministère de l'Économie, de la Science et de l'Innovation du Québec was specifically designed to create partnerships between businesses or non-profits and universities to facilitate the transfer of expertise. Under the new partnership, UQAM would continue the development of SCHEMA with MapGears and its GIS specialist would integrate the data and create the application. Another team based at UdeS pursued the development of a 3D viewer integrated with the mapping platform which will be presented in a future paper.

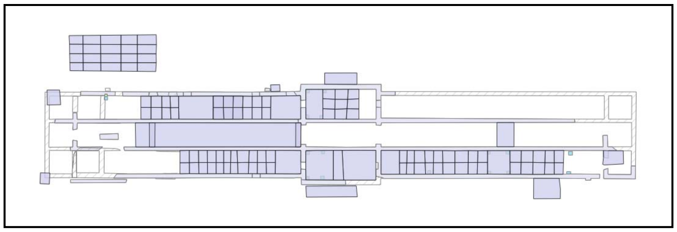
IV. CREATING THE GIS VISUALIZATION SYSTEM

The project uses existing data collected from a series of excavations (1980, 1989, 2011 to 2013, and 2017). As in the case of the pilot project, the data needed to be adapted for spatial analysis. On the programming side, we could rely on experienced partners to deliver the software improvements required.

A. Data Management (Layers and Attributes)

Each excavation campaign generated its own set of maps from on-site surveys, but they were never consolidated into a single layer covering the entire area. Therefore, one of the first tasks was importing the surveys available as dxf files and anchoring them on their appropriate location. The result (Fig. 3) provided the first complete georeferenced view of the site with each excavation lot.

Fig. 3. Plan of the excavation suboperations with building outline



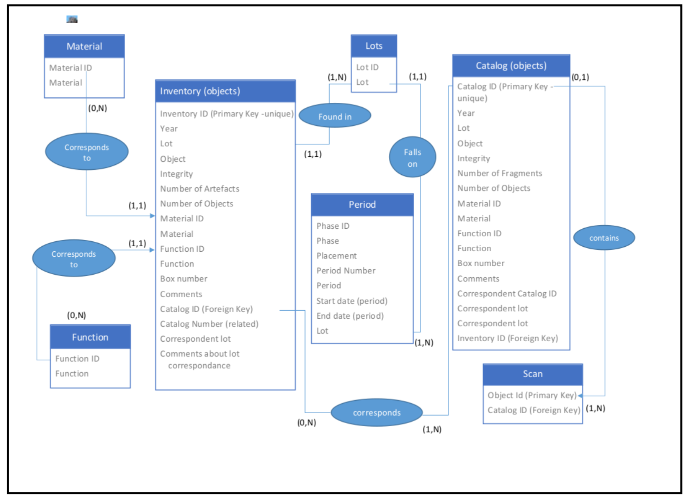
Data from the six excavations was integrated into the database format prescribed by the city. For any given artifact, archaeologists enter the following descriptive information: name, material and function. Other metadata includes the year and the location of recovery, the storage location, and the level of integrity. Links are made to associate fragments that are part of the same object or objects forming a set. In the latter case, it is possible, for example, to identify elements from place settings recovered from the dining area. The original database consisted of two similar tables, *Inventaire* and *Catalogue*. The first must comply with municipal regulations to describe all artifacts recovered from the six campaigns, while the second was designed for municipal and internal use to manage the objects integrated into the collection.

Each item is georeferenced to its excavation square and to its strata, but it does not easily lend itself to map visualizations, given that there are too many categories in each typology to generate easily readable maps. Fields were added to render category names more explicit to a broader range of users, and codes were replaced with full words. Data conversion is automated with a set of formulas so that new data can be integrated with limited human intervention. The improved database is shared with the Museum to facilitate update management and avoid desynchronization. The original structure was maintained to ensure compatibility with municipal regulations, which means that the relational model cannot be fully normalized. However, the additional fields and tables provide a more efficient structure for queries and analysis and will make it possible, in the future, to link objects with scanned 3D copies (Fig. 4).

B. Advanced Visualization Functions

On SCHEMA, a set of viewer tools were added to the interface to create an application with map, tabular data, and graphs. The standard view for the application is a georeferenced plan on the right half of the screen. The left panel provides full tabular data on each artifact with space at the bottom where a matrix displays the importance of different types of artifacts for the complete site, a selected area or a given square (Fig. 5).

Fig. 4. Database structure

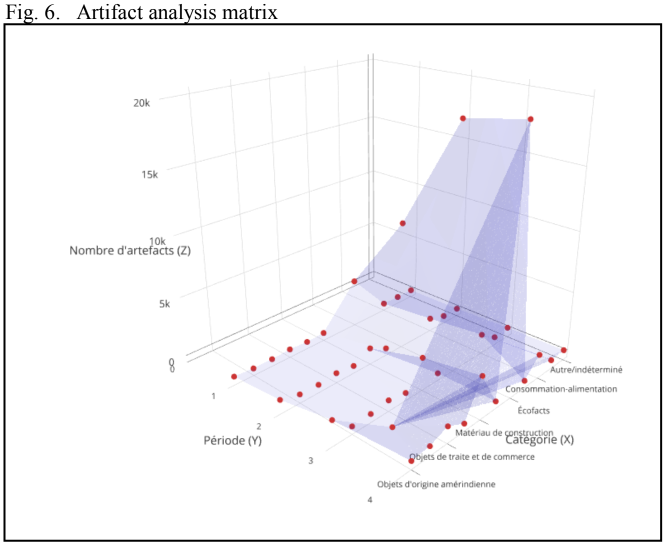


Filters offer the possibility to select an area by radius, or by drawing a square or a polygon. The lot filter allows the user to click on any polygon to analyze a specific square on the grid. The data can be queried using seven fields which can be combined as "and" queries. Drop-down menus are available for each category to facilitate searching by people less familiar with the data. A full-text search box is also available to provide a quick access to any word in the database. The full database or the results of any query can be exported for use in other systems, either as a shapefile or as a list of comma separated values (csv).

Fig. 5. General application interface with map, data and matrix

Our team had explored the idea of using a cross-section view of the site to show the distribution of various artifacts. Given that we could not achieve the type of 3D view required in the application, we opted for a matrix. The x-axis is used to display categories while the y-axis shows the period of origin (determined from the strata where the artifact was found) and the z-axis indicates the number of items for a given category in that time period. Hovering over a given point in the matrix triggers an information bubble containing the name of the category, the time period and the number of items (Fig. 6).

Fig. 6. Artifact analysis matrix



Given the nature of the site and of its preservation, this information can be used to analyze the distribution of the different types of artifacts and offer insights into the functions of the various areas of the building, especially since the historical record does not provide many details on the specific use of the rooms after it was converted into a parliament house. This analysis can be performed in three dimensions, considering that the floors collapsed and that basements where debris collected were then covered to erect a new building on the same foundations. Construction materials were largely removed from the site, but objects of common use in the assembly, council, eating rooms, and libraries were mainly untouched. As a result, we found books, a pair of eyeglasses, a government seal, glassware, porcelain, and cutlery. We believe that the vertical position of the objects in the strata associated with the 1849 fire could indicate on which floor the objects were originally located. This will be the subject of further study.

C. *Use by the Museum*

The platform will allow the chronological and spatial exploration of a tremendously numerous and diverse dataset. It will be used by the archaeologists to prepare the final report on the 2017 excavations and a complete synthesis of the site's occupation and use. The application will present distribution of different kinds of objects within the building and according to their stratigraphic position. The data will be used to study how the walls collapsed during the fire of 1849. It will also be possible to cross-examine the distribution of different kinds of objects or different objects related to broad functional categories (food preparation and consumption, hygiene, clerical work) or materials, highlighting the internal spatial organization of the building. All queries can then be exported in different formats as raw data for further statistical investigations. In sum, the application solves many problems that arise from the manipulation of large, diverse archaeological collection recovered from a large site with a deep, but significant stratigraphy.

V. Conclusion and Future Work

Large artifact collections present specific sets of challenges for analysis. The Museum's traditional database could provide certain types of analysis based upon artifact type and location. However, this was only accessible to a small number of specialists who knew the codes for both typology and location. The transfer to a GIS platform and the conversion of the typology to a more explicit terminology facilitates the visualization of location and makes the information accessible to a broader range of professionals within the institution.

This partnership made it possible to develop a system which will help the Museum manage and analyze the large collection resulting from excavations at place D'Youville. Researchers will better understand the spatial and stratigraphic distribution of artifacts, which can help define the function of various sections in the full 3D model of the building already created. Work is currently under way to integrate a 3D viewer to the application so that users may view representative objects from different categories. Furthermore, while we developed this system to resolve data management issues, we believe that it can be used as an infrastructure to provide data and visualizations for virtual explorations either as an interactive kiosk or a web application.

Acknowledgment

Among our many collaborators, we would like to thank Louise Pothier, Laura Barreto Palacio and Simon Mercier.

References

[1] "Place d'Youville," Inventaires du Vieux-Montréal. http://vieux.montreal.qc.ca/inventaire/fiches/rech_rues.php

[2] G. Lock and J. Pouncett, "Spatial thinking in archeology: is GIS the answer?," in Journal of Archaeological Science, vol. 84, 2017, pp. 129-135.

[3] P. Neruda, "GIS analysis of the spatial distribution of Middle Palaeolithic artifacts in Kulna Cave (Czech Republic)," in Quarternary International, vol. 435, Part A, 2017, pp. 58-76.

[4] I. Grau Mira, "Archaeological surveys in areas with a high density of artifacts: Analysis and interpretation proposals," in Quarternary International, vol. 435, Part B, 2017, pp. 71-80.

[5] The OIC Weave Open Source Data Visualization project is no longer accessible via http://oicweave.org, but a summary presentation is still available at the GIS Lounge. https://www.gislounge.com/weave-open-source-data-visualization/

[6] N. Charbonneau and A. Thirion, "Le recours aux technologies numériques pour l'étude de contenus à caractère historique et archéologique," in J. Burgess and P.-A. Linteau, De l'Histoire au Patrimoine: État des Lieux et Perspectives, Québec, Presses de l'Université du Québec, to be published in 2019.

[7] eVouala - Understanding Where!, http://evouala.com/.

[8] L. Robichaud, "Prendre le tournant spatial en histoire. Le Laboratoire d'histoire et de patrimoine de Montréal et le Système de cartographie historique de Montréal (SCHEMA)," in J. Burgess and P.-A. Linteau, De l'Histoire au Patrimoine: État des Lieux et Perspectives, Québec, Presses de l'Université du Québec, to be published in 2019.