Shapes and Uses of Greek Vases
(7th– 4th centuries B.C.)

Edited by
Athena Tsingarida

ÉTUDES D'ARCHÉOLOGIE 3

Éditeur

CReA-Patrimoine

Université libre de Bruxelles
50, av. F.D. Roosevelt / CP 175
B-1050 Bruxelles
crea@ulb.ac.be

ISBN : 9789077723852
Impression : Le Livre Timperman

Couverture

Stamnos signed *Smikros egrapsen.* Side B, man and youth filling a dinos (inv. A717)

Études d'archéologie 3
Études d'Archéologie Classique de l'ULB 4

Calculating vessel capacities : A new web-based solution

Laurent Engels, Laurent Bavay & Athena Tsingarida

Pottery studies and vessel capacities

Whether they are used for cooking, service, storage or transport, the primary function of vases is to contain products, either solid or liquid. Vessel capacity therefore appears as an important element for the definition of use and function, but also for classification purposes as well as for discussions of craft specialization[1].

Size, as reflected by the capacity of the vessel, probably had more importance in the way ancient potters and users regarded pottery than it is given in our archaeological typologies. The potters accounts from La Graufesenque in Southern Gaul, recording kiln batches of terra sigillata in the first and second centuries AD, show that these craftsmen did not classify their production according to the categories commonly used by the modern archaeologists (such as plates, bowls) but according to the size of the vessels[2]. Likewise, papyrological sources indicate that some capacity measures in Roman and Byzantine Egypt were closely related to certain types of pottery containers[3]. These examples illustrate the close ties between pottery classification and vessel capacity.

Comparison of vessel capacities also represents a useful and appropriate way to evaluate the standardization of the production, with implications on issues such as craft organisation and specialization in ancient societies[4], the existence of standard modules for particular types of containers etc.

Although these aspects have long been recognised, vessel capacities received but little attention in pottery studies of the Graeco-Roman world[5]. This situation can be explained partly by the often fragmentary nature of the ceramics from excavations, which makes direct measurements difficult. Another reason is probably related to the complexity of calculating vessel capacities from traditional graphic documentation.

Methods of calculating vessel capacities

Several methods can be used to determine the capacity of a vessel[6]. These methods are based either on direct measurements or on indirect calculation.

Direct measurement methods consist in filling in the vessel with water or a free-flowing solid (sand, rice, lentils etc.), which then provides a direct measure of the capacity of the container. Although these methods are relatively easy to implement and do not

[1] See the articles of A. Clark and E. Böhr in this volume (p. 89-109 and p. 111-127).

[2] These accounts are published by R. Marichal, *Les Graffites de La Graufesenque*, 47e supplément à *Gallia*, 1988.

[3] See a.o. N. Kruit, K. Worp, "Metrological Notes on Measures and Containers of Liquids", *Archiv für Papyrusforschung* 45 (1999), 96-127 ; D.M. Bailey, *Excavations at el-Ashmunein, V. Pottery, Lamps and Glass of the Late Roman and Early Arab Periods*, London, 1998, 129-130.

[4] A.o. C. Costin, "Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production", *Archaeological Method and Theory* 3 (1991), 1-55.

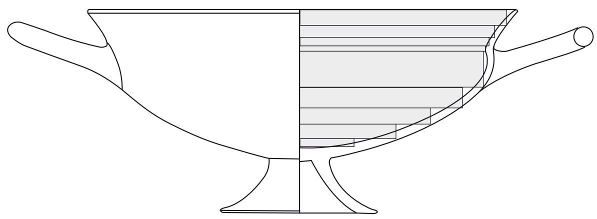
[5] Among few exceptions, see M. Bentz, with a contribution by E. Böhr, "Zu den Maßen attischer Feinkeramik", *in:* M. Bentz (ed.), *Vasenforschung und Corpus Vasorum Antiquorum. Standortbestimmung und Perspektiven*, München, 2002 [*Beihefte zum CVA* I], 73-81; for an early attempt, see the pioneering study of M. Egloff, *Kellia. La poterie copte. Quatre siècles d'artisanat et d'échanges en Basse-Égypte*, Geneva, 1977, 23-24.

[6] Reviewed in details, with relevant references, by L.M. Senior, D.P. Birnie III, "Accurately Estimating Vessel Volume from Profile Illustrations", *American Antiquity* 60, 2 (1995), 320-325.

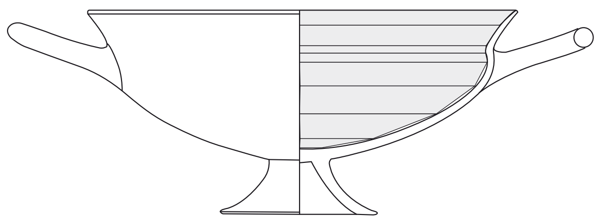
necessitate complex calculations, their use encounters practical drawbacks. Notably, they can only be applied to complete or reconstructed vases, which normally represent only a very limited percentage of the archaeological vessels. The use of water, sand or other material may also represent a threat for the conservation of the vases, due to pressures, weight, chemical reactions etc. For that reason it will usually not be allowed on museum objects (and thus on the majority of the Greek figure-decorated vases). Lightweight polystyrene packing material known as styropore and supposed to be chemically inert is therefore frequently used for that purpose ; however the small balls made of this material tend to pack with voids between them and the results therefore will be less precise.

Methods based on calculation consider the vessel volume as the addition of cylinders stacked one above the other, from base to rim (hence the name "stacked cylinders method"). Therefore the vase is divided into a series of horizontal slices (fig. 1). The volume of each slice is obtained by the formula: $V = \pi R2H$, where R is the radius and H the height of the slice. The sum of the volumes gives the total capacity of the vessel. The overall precision increases with the number of slices. Different variants of this method have been proposed to improve the precision of the measurement, such as the "bevel-walled cylinders" technique[7]. Instead of using vertical-walled cylinders, the algorithm incorporates the calculus for cylinders with slanted edges (fig. 2), thereby allowing to follow more precisely the profile of the vessel. The volume of each bevelled cylinder is obtained by the formula : $V = \pi H/3 (R12 + R1R2 + R22)$, where H is the height of the cylinder, R1 is the top radius and R2 is the bottom radius. The total volume of the vessel is obtained by the sum of the successive bevelled cylinders volumes.

Calculation methods present the advantage that access to the object is not needed ; measurements are taken on scale drawings, offering the possibility to work on published material (and thus also facilitating comparative work). Furthermore, these methods are applicable on fragmentary vessels and do not require the physical reconstruction of the fragments. However, the accuracy of the results will depend upon the precision of the drawing. A major drawback of these methods is the large number of measurements and complex calculations involved. Some attempts have therefore been made to develop computer-aided solutions. Most of these remain unpublished or rather confidentially distributed, while those offered to a wider audience still require time-consuming measurements[8] or remain operating-system dependent[9]. The rapid development of computer and information technologies (IT), together with the now widespread access to broadband internet connections, also provide new possibilities which were not available for solutions developed only a few years ago[10].



1. Calculating the volume by the stacked cylinders method (the size of the cylinders is exagerated on the figure)



2. Variant of the former method, the bevelled walled technique

[7] L.M. Senior, D.P. Birnie III, "Accurately Estimating Vessel Volume from Profile Illustrations", *American Antiquity* 60, 2 (1995), 324-330.

[8] E.g. the solution developed by the Centre d'Études alexandrines and based on the commercial software FileMaker Pro™ : http://www.cealex.org

[9] E.g. the program developed by Jean-François Meffre and Yves Rigoir and available for download on the website of the Société française d'étude de la céramique antique en Gaule (SFECAG), for Windows only : http://sfecag.free.fr/contenance.htm

[10] L.M. Senior, D.P. Birnie III, "Accurately Estimating Vessel Volume from Profile Illustrations", *American Antiquity* 60, 2 (1995), 319-334.

A new applet, algorithm and implementation

Within the context of the five-year research programme "Pottery in ancient societies: production, distribution and uses"[11] organised by the Archaeological Research Centre (CReA), archaeologists and civil engineers[12] of the University of Brussels teamed up to develop a new tool which would facilitate the calculation of vessel capacities. The application had to meet the following specifications: the possibility to use existing documentation of the vessels (drawings) with minimal adaptations, to automate the measurements as well as the calculations, to provide a user-friendly interface and to offer the largest availability and accessibility as well as possibilities to improve the programme on the basis of users' feedbacks. It was decided that the most adapted answer to these requirements would be a web service, in the form of an applet which would be accessible to any machine connected to the internet. The advantages of the web-based applet on a freestanding program are that the user does not need to install any software on his machine, the applet is operating-system independent (it works on Windows, MacOS and Unix) and browser independent (it works with any recent web browser).

The calculation is done from a computer file which contains the profile's representation of the vessel. Since it is very popular, light and open, the JPEG format has been chosen. Vectorial drawings which are often used for this kind of archaeological drawings can also be very easily converted. A bitmap image, like the JPEG format, is an image which is encoded using pixels, comparable to a large matrix in which each element is a pixel and each pixel can get a different colour. But this file does not contain any information about the geometry of this image, such as lines, circles etc. Algorithms therefore must be used to group those pixels in known shapes.

Looking on a vessel drawing, we have the profile on one side, the contour line on the other side, the symmetry axis, as well as some details like texts or small lines representing manufacture marks, articulations etc. The main goal is to extract the axis and the profile.

[11] This research project, "Action de Recherche Concertée" (ARC 2004-2009), is funded by the Belgian Ministry of the French Community.

[12] Laboratory of Image Synthesis and Analysis under the direction of Prof. Nadine Warzée.

Axis extraction

The revolution axis is typically a vertical line located near the centre of the drawing. Since this line is not precisely in the middle of the image, sometimes even much more distant, the program has to detect it. The popular Hough transform algorithm has been used for detecting lines in an image. This method consists in finding lined up pixels and deducing from them the characteristics of geometric lines. An advantage of this algorithm is that the program can consider continuous lines but also dashed ones. The vertical lines are kept and if it remains more than one, the program will retain the one which divides the vessel in the two most symmetrical parts, since we consider objects of revolution. The tests prove this method to be very robust.

Profile extraction

The profile extraction is certainly the most difficult part in this process. Not only the profile itself must be extracted, but it is also necessary to identify which is the interior side. Indeed, considering the external side when filling the vessel would affect the measure. There exist several methods to regroup connected pixels into regions. But as there is some variation in the way the profile is represented in archaeological drawings (filled in black or left blank), some algorithms which use region's area can not be utilized. Hence it has been preferred to analyse external contours instead of whole regions.

After the computation[13] of the contours of each region of the part of the drawing that the user has selected (profile on the left or right side) and after the profile which corresponds to the contour with the biggest bounding box has been found, we can analyse the curve to separate the internal and external sides. To determine the interior side, we follow the contour in the counter clockwise direction, starting from the top. Characteristic points are extracted. Using the proximity of the axis and the presence of other points on the top or below the studied point, it is possible to determine the interior side which will start from the top of the contour and to the given characteristic point.

[13] S. Suzuki, K. Abe, "Topological Structural Analysis of Digital Binary Images by Border Following", *Computer Vision and Graphical Imaging Processing* 30, 1 (1985), 32-46.

Capacity computation

To calculate volume, the curve of the profile is divided so that each part is linear. For each one of these parts, a rectangle is calculated. Its height (H) is equal to that of the part and its length (R) is the distance between the axis and the centre of the part. The volume is found using the formula:

$$V = R^2 H \pi$$

Thus, this rectangle precisely represents the volume of the part which it symbolizes. The total volume of the vessel is the sum of all the rectangles.

Using the applet, some practical informations

The applet is accessible via the homepage of the Archaeological Research Centre of the ULB, at the following URL: http://crea.ulb.ac.be

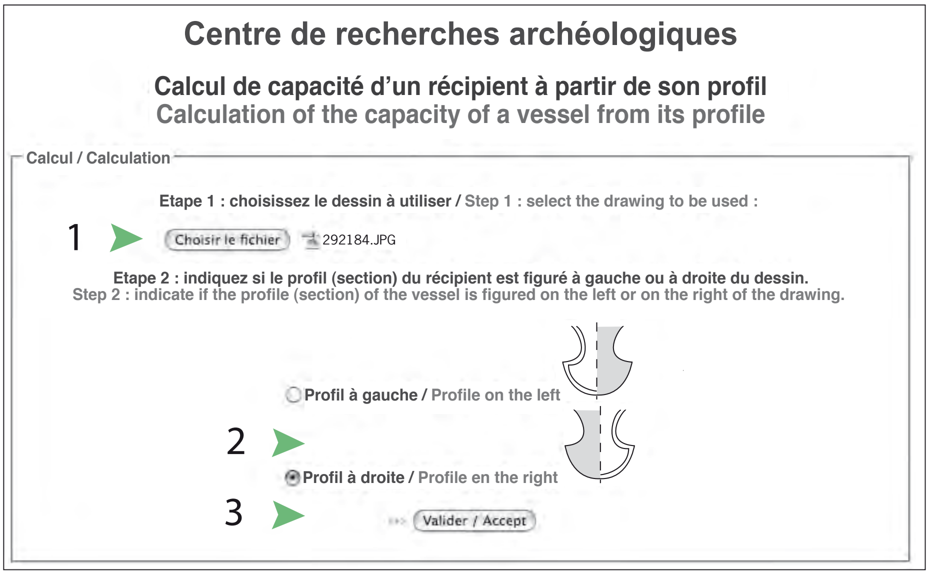
The use of the applet is free and unlimited. The users are asked, however, to register on their first visit, using a login and password of their choice (fig. 3). The informations asked for the registration (institution and email address) are intended to provide information about future updates of the applet, as well as to help improve the advertising of the site. These informations will not be provided to any person outside the project staff, and will not be used for any purpose unrelated to the project.

Once logged in, the next frame allows to upload the drawing to be measured (fig. 4). This requires two steps. First the user selects the drawing to be calculated, using the "select drawing" button. Typically, this file is stored on the user's hard disk. The drawing should be inked, and saved as a JPEG file (compressed bitmap image file). Examples are given on the webpage showing some features in drawings which could alter the measurement or its precision. Second step, the user indicates if the profile is situated on the right or left side of the drawing, by checking off the appropriate field. Note that the server does not keep any uploaded file, these are deleted on a daily basis.

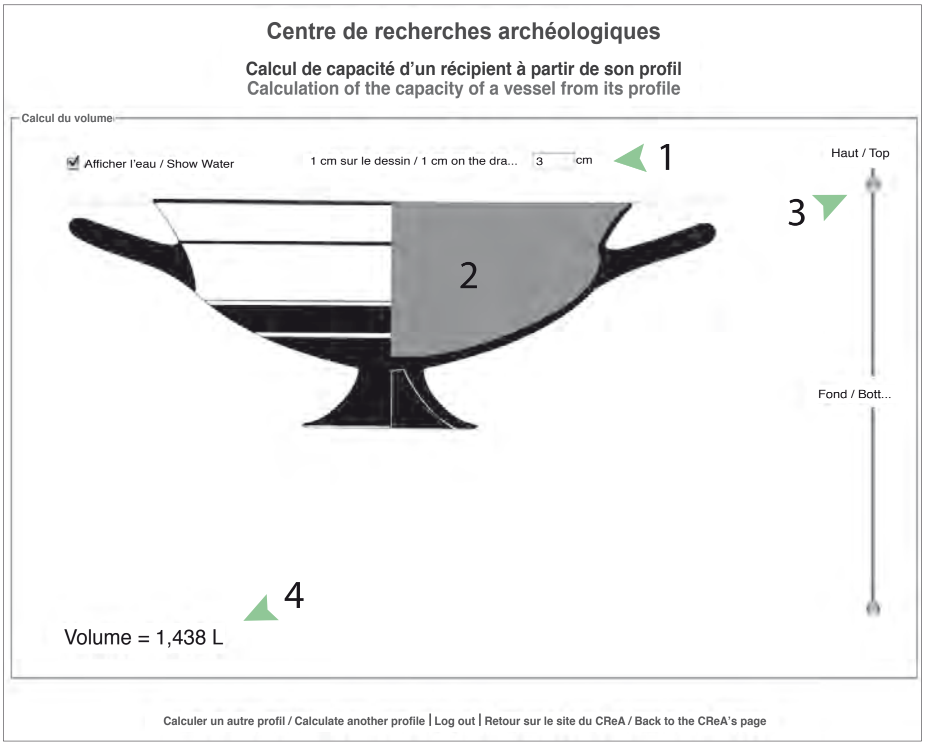
Once uploaded, the drawing appears in the next frame (fig. 5). The resolution of the image (e.g. 150 dpi) is automatically recognised. The user however has to indicate the scale of the drawing. The default value is scale 1:1 (1cm on the drawing is 1 cm). If the drawing is a reduction, the scale has to be indicated in the appropriate field (e.g. 1 cm on the drawing is 4 cm, for scale 1:4). The filling of the vessel is represented in blue colour. By default, the vessel is filled from bottom to rim. The total volume is indicated under the drawing, in litre. A scroll bar on the right of the frame allows the user to modify the level of the filling. The result is updated in real-time when the scroll bar is moved upwards or downwards. A button "calculate another profile" at the bottom of the frame brings back to the upload page in order to select a new drawing to measure.

Feedback is most welcome from those users who might encounter any problem or have any suggestion for the improvement of the applet.

3. "Log in" window. On first visit, create a new account



4. "Select drawing" window
Step 1 : select the drawing to be used
Step 2 : Indicate if the profile of the vessel is figured on the left or on the right side of the drawing
Step 3 : Send your drawing using the Accept button



5. "Calculation" window
1 : Indicate the scale of the drawing (here, 1 cm on the drawing is 3 cm, or scale 1:3)
2 : The inner part of the vessel is filled in up to the rim (represented in blue colour)
3 : The scroll bar allows to modify the level of the filling
4 : the total volume of the vessel is calculated and updated in real time

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