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*Short and Project Papers*

# IBISA: Image-Based Identification/Search for Archaeology

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**Abstract**

*IBISA (Image-Based Identification/Search for Archaeology) is a research project supported by the French CNRS. The corresponding software tool manages databases of digital images of archaeological objects, and allows the user to perform searches by examples. For now, the system works with ancient (greek, roman) coins, and the generalization to medieval tiles is under progress. IBISA was designed to help the user decide, from their images, if two objects are either the same, come from the same matrix, share resemblance in style, or are completely different. It uses computer vision methods to make this decision while getting rid of the viewing conditions when searching for similarities in the databases. First, a segmentation method based on active contours extracts the useful part of each image from its background context. Then, a registration method based on the Fourier-Mellin transform sorts the images by similarity, canceling any translation, rotation, or zoom inherent to the photography.*

Categories and Subject Descriptors (according to ACM CCS): I.3.8 [Computer Graphics]: Applications, I.4.3 [Image Processing and Computer Vision]: Registration, I.4.6 [Image Processing and Computer Vision]: Segmentation, I.4.9 [Image Processing and Computer Vision]: Applications.

## 1. Introduction

As the use of digital images gets generalized in archaeology, computer vision techniques are getting always more crucial. As shown recently in [ZKS08], they apply to numismatic research. It was also our guess [Mar04], and after some years the IBISA project is now ready to release its associated free software tool (for Windows, Mac OS, and Linux operating systems). It manages databases of digital images (in common file formats such as JPEG, TIFF, etc.) of archaeological objects (up to a few thousands), and allows the user to perform searches by examples. For now, these objects can be either ancient coins [Bre05] or medieval tiles [Cic06].

By taking advantage of the similarity among large finds (coin hoards, tile pavements), one could guess the original fabrication process, chronology, geography, or even economical or social issues. The difficulty is to handle a large number of objects, very similar at first sight for a non-specialist, and to compare them. This task is time-consuming, quite exhausting, and thus error-prone. IBISA was designed to help the user decide, from their images, if two objects are either the same, come from the same matrix, share resemblance in style, or are completely different.

The remainder of this article is organized as follows. Section 2 presents the archaeological objects under consideration and their digital images, together with the problematics they raise. Section 3 focuses on the main functionality of the IBISA software: the search by example inside an image database, sorting the results by similarity. Finally, Section 4 concludes by giving directions for further research.

## 2. Archaeological Data

### 2.1. Physical Objects

The archaeological objects are only required to be quasi flat (two-dimensional) and produced from matrices via some striking / stamping / casting process. The original matrices are generally lost now, but many objects with their prints can still be found, with many similarities among them, although these objects underwent some alteration (wear, patina, or even breaks) over centuries. For now, the system works with ancient (greek, roman) coins, and the generalization to medieval tiles is under progress.

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(a) (b)

**Figure 1:** *Silver coin (denarius) of the Roman Republic (issued by moneyer T. Carisius in 46 BCE), showing on the obverse (a) the head of Juno Moneta and on the reverse (b) an illustration of the process for striking coins: each metal flan was placed between the anvil die (bottom) and the punch die (top), hold by tongs (left), then struck with a hammer (right) [credits: Numismatica Ars Classica].*

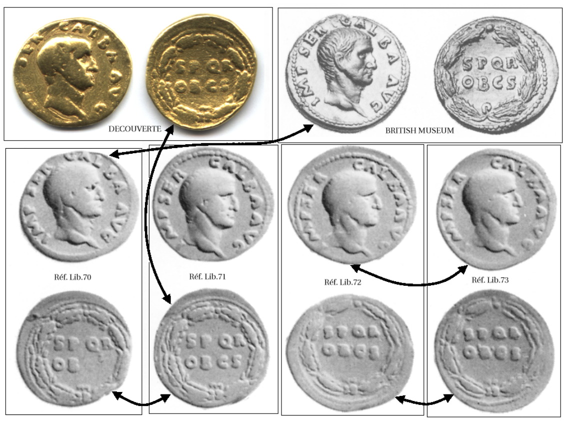



**Figure 2:** *Studying ancient coin hoards: die links (see arrows) for 6 Roman gold coins (aurei) of the Emperor Galba (68–69 AD) – an exemplar under investigation [PPS08] (upper left corner), an exemplar of the British Museum [Sea00] (upper right corner), and the 4 exemplars from the Liberchies hoard [Thi72] (bottom). It turns out that the first coin is indirectly linked to the one in the British Museum.*

### 2.1.1. Ancient Coins

In the case of ancient coins, a design was engraved on a metallic die, used in turn often by pair (obverse / reverse) to strike the coins, as illustrated in Figure 1 for the Roman period. The original dies are now lost, but many coins can still be found, sharing many similarities among them. IBISA should allow the user to identify an isolated specimen and facilitate the study of coin hoards, as shown in Figure 2.

### 2.1.2. Medieval Tiles

In the case of medieval tiles, a design was carved on some wooden pattern block, used in turn to stamp the earthenware tiles [Eam81, Cic06]. The original blocks are now lost, but many tiles can still be found, sharing many similarities among them (see Figure 3). IBISA should allow the user to identify a design and facilitate the study of tile pavements, as shown in Figure 4.

**Figure 3:** *Medieval glazed earthenware tiles from the castle of Villandraut (France, 14th century), with exactly the same design thus stamped with the same block.*

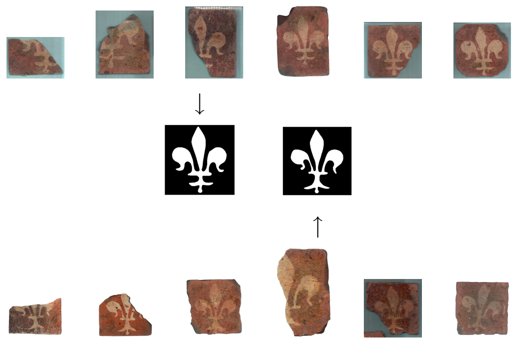


**Figure 4:** *Studying medieval tile pavements: 2 different designs for the fleur-de-lys – tiles of types A (top) and B (bottom); and the corresponding reconstructed designs (middle).*

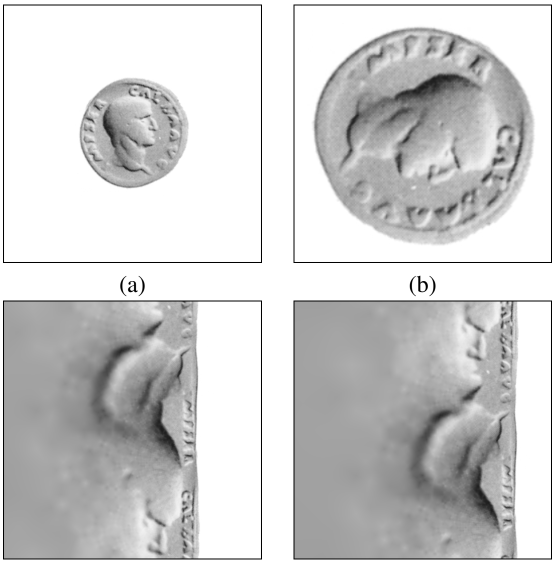
## 2.2. Digital Images

It is more convenient to manipulate digital images instead of the archaeological objects themselves. One can photograph or scan the objects, or even use existing pictures from books or databases. Our system must be resistant to the viewing conditions, since they are generally unknown. Pictures from books often lack the chromaticity information and suffer from Moiré patterns. Also, sometimes the scale is not specified. Pictures from camera nearly always lack this scale information, and are neither perfectly centered nor aligned.

To get rid of the colorimetry and Moiré problems, our system manipulates gray-scale images in the spectral domain. In this paper, we will neglect other effects (*e.g.* shading), and rather focus on the resistance to rigid transformations.

Let us denote by $g(p)$ the (gray-scale) value of the image $g$ at the point $p$. A geometric transformation is defined by

$$T: \quad p \mapsto p' = T(p), \tag{1}$$



(a) (b) (c) (d)

**Figure 5:** *Effects of a rotation of angle* $\pi/2$ *rad plus an homothety of ratio* 2 *in Cartesian (top) and log-polar (bottom) coordinate systems: In the Cartesian case, the original picture (a) gets rotated and scaled (b), whereas in the log-polar case, the original picture (c) is simply translated (d) by* $(\log(2), \pi/2)$*, see Equation (5).*

$$g \mapsto g', g'(p') = g(p). \quad (2)$$

A translation of vector $t = (\Delta_x, \Delta_y)$ can be easily expressed using complex numbers with the Cartesian form:

$$\begin{array}{rl} & p' = p + t \\ \text{where} & p' = x' + iy', p = x + iy, \\ \text{and} & t = \Delta_x + i\Delta_y. \end{array} \quad (3)$$

For a rotation+homothety of angle $\phi$ and ratio $s$, the polar form is more suitable:

$$\begin{array}{rl} & p' = r \cdot p \\ \text{where} & p' = \rho' e^{i\theta'}, p = \rho e^{i\theta}, \\ \text{and} & r = \underbrace{s}_{\text{homothety}} \cdot \underbrace{e^{i\phi}}_{\text{rotation}}. \end{array} \quad (4)$$

As shown in Figure 5, this rotation+homothety is equivalent to a translation in the log-polar representation, since:

$$\log(p') = (\log(s) + i\phi) + \log(p). \quad (5)$$

Without loss of generality, any rigid transformation – very likely to occur in photographs – can be expressed as one translation followed by one rotation+homothety:

$$p' = (p + t) \cdot r. \quad (6)$$

## 3. Identification and Search

The IBISA system manages databases of images. From a given image, the system is able to sort the other images by decreasing similarity. From the system will come out first the same object with different viewing conditions, then other objects coming from the same matrix, objects of the same style, and finally very different objects. This functionality – extremely useful for the semi-automatic study of die links in coins hoards or the use of designs among tile pavements – is done thanks to a 3-step process: segmentation, registration, and similarity computation.

### 3.1. Segmentation

First, a segmentation is performed on the target image to get rid of its background context, that would interfere with the registration process (see below). An initial shape is given to an active contour [KWT88], deformed in the image until it matches the outlines of the object of interest. This is achieved by an energy minimizing process: for each shape drawn in the image, one can define an energy which is low when the shape is regular (low curvatures) and when it corresponds to image contours (high gradient). This yields much better results than the classic "magic wand", especially for coins, which are nearly round – with a low curvature.

### 3.2. Registration

A registration method, based on the Fourier-Mellin transform [WZ00], is then used to find the optimal superposition of the two images. It works in the spectral domain, using the spectrum $G$ of the image $g$:

$$G(\omega) = \int_p g(p) e^{-i\omega \cdot p} dp \quad (7)$$

and two of its properties:

1. The translation does not modify the amplitude spectrum (its only effect is a phase shift).
2. The spectrum of a rotated image is the rotation of the spectrum of the original image (similar property for the homothety, but with the inverse ratio).

Recovering a translation

$$g'(p') = g(p' - t) \quad (8)$$

considering the spectral domain

$$G'(\omega) = G(\omega) \cdot e^{-i\omega t} \quad (9)$$

is possible using the phase-correlation technique. We have

$$\frac{G^*(\omega) \cdot G'(\omega)}{|G^*(\omega)| \cdot |G'(\omega)|} = \frac{G^*(\omega) \cdot G(\omega) \cdot e^{-i\omega t}}{|G(\omega)| \cdot |G(\omega)|} = e^{-i\omega t} \quad (10)$$

(since $G \cdot G^* = |G|^2$, $G^*$ being the conjugate of $G$), and its inverse Fourier transform is an impulse located at $t$. Thus, estimating $t$ is only a matter of searching for a maximum.

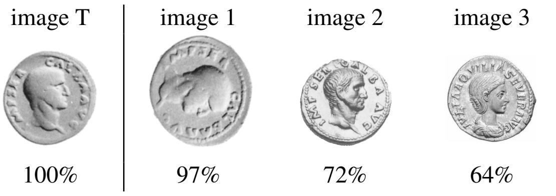



**Figure 6:** *Similarity between images: the leftmost image is the target T, followed by the result of a search by example in our test database. The similarity factor is indicated below the images. The coin on image 1 is indeed from the same die – and the system suggests for T a translation, a rotation of angle $-\pi/2$ rad, and an homothety of ratio 1.5, for the two coins to superimpose optimally (97% of similarity). The next coin (image 2) is of the same type (but not of the same die), and the coin on image 3 is not even from the same Emperor.*

Recovering a rotation+homothety

$$g'(p') = g(p'/r) \tag{11}$$

is not more difficult, since it reduces in the log-polar representation to the translation case, thanks to Equation (5).

Finally, the full registration algorithm is the following:

1. find the rotation+homothety $r$ (estimate $(\phi, s)$)
   - by finding a translation in the log-polar system,
   - by considering the amplitude spectra of the images (to ignore the effects of the translation $t$);
2. invert the rotation+homothety (rotation of angle $-\phi$ and homothety of ratio $1/s$);
3. find the translation $t$ (estimate $(\Delta_x, \Delta_y)$), now free from any rotation or homothety;
4. invert the translation (translation of vector $(-\Delta_x, -\Delta_y)$).

### 3.3. Similarity

After this registration, the similarity between the two images is computed using the classic inter-correlation factor, yielding very good results in practice, as shown in Figure 6.

## 4. Conclusions and Future Work

In this article, we have introduced the IBISA system that manages digital images of archaeological objects and helps the user study ancient coins hoards or medieval tile pavements, by discovering similarities. The system takes advantage of computer vision techniques. For now, they were tested only with small numismatic databases. To be fully functional with earthenware tiles, the segmentation method has to be enhanced, and – most important – the system has to handle fragments of objects. This is part of our future research, as well as the evaluation / validation of the system on real – large – databases.


**Figure 7:** *Snapshot of the IBISA software tool, illustrating the registration – here in manual mode and with on-purpose error – of the target on a similar image. Because of the registration error, the similarity factor (bottom) is very low (5%).*

The project homepage is http://dept-info.labri.fr/~sm/Projets/IBISA/, and the software is available as a SourceForge project: http://ibisa.sourceforge.net/

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