

# Virtual Restoration of Fragmented Glass Plate Photographs of Archaeological Repertoires

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## Resumen

*Este papel describe un pipeline virtual de restauración para los platos rotos de cristal en el fondo del Departamento de Estudios Arqueológicos, Filológicos e Históricos de la Universidad de Catania. Este archivo incluye raras imágenes de las actividades de excavación del Departamento en Sicilia y Grecia. Muchos de los platos son dañados y fracturados y requieren una reorganización y una restauración virtual. Se puede aplicar a este caso un algoritmo de restauración que se basa en el uso de las técnicas de procesamiento de la imagen. El algoritmo aumenta la calidad de las imágenes digitalizadas y sucesivamente realiza una rígida matriculación y la realineación de los fragmentos. Una aplicación final de la técnica de inpainting llena los vacíos.*

**Palabras Clave:** REPERTORIOS ARQUEOLÓGICOS, PLATOS DE CRISTAL, RECONSTRUCCIÓN AUTOMÁTICA, INPAINTING

## Abstract

*This paper describes a virtual restoration pipeline for the broken glass plates in the fund of the Department of Archaeological, Philological and Historical Studies of Catania University. This archive includes rare images of the excavation activities of the Department in Sicily and Greece. Several of the plates are damaged and fractured and require virtual realignment and restoration. We adapted to this case a restoration algorithm based on the use of image processing techniques. The algorithm enhance the quality of scanned images, and subsequently performs a rigid registration and realignment of the fragments. A final application of inpainting techniques fills the gaps.*

**Key words:** ARCHAEOLOGICAL REPERTORIES, GLASS PLATES, AUTOMATIC RECONSTRUCTION, INPAINTING

## 1. INTRODUCTION

The Department of Archaeological, Philological and Historical Studies (S.A.FI.St.) of Catania University has recently started a digitalization project of its textual and iconographical fund, one of the largest and oldest among Italian Academies. In this effort a serious problem is represented by the glass plates coated by silver halides. The Library has an archive of about 3000 of these glass plates taken between the two last decades of the '800 and the first half of the '900, depicting the masterpieces of Greek and Roman art, used during teaching sessions and documenting the excavation activities of the Department in Sicily and Greece.

In particular, in the first half of the XX century, the archive was enriched thanks to Guido Libertini (1888-1953), full professor of Classical Archaeology at Catania University from 1926, dean of the Faculty of Classics between 1937-39 and 1944-1947 and chancellor from 1947 to 1950. Several glass plates, from those fragmented selected as case studies, are related to the studies and excavations at Centuripe (Enna, Sicily), promoted by Libertini and later carried out by Giovanni Rizza (LIBERTINI 1926, RIZZA 2002).

This heritage represents an important historical documentation of the past activities registered on a unique support (CHÉNÉ et alii 1999). This type of support represented an important step

forward in the evolution of photographic materials but, already at the time of its use at the Department of Archaeology (LEANZA in press), it was outperformed by the newborn roll-film using cellulose nitrate base, invented by George Eastman (1854-1932). However, it was still used in some specific disciplines, including archaeology, because the disadvantages related to its higher cost and the size of the photographic equipments were compensated by an incomparable rigidity of the support, essential feature to obtain sharp images, and by its chemical stability coupled to the impossibility of a spontaneous combustion. All these positive features came however with a major disadvantage: the fragility of the support (DORRELL 1984).

Several of these plates are damaged and fractured, they cannot be used for reproduction and cannot be properly digitalized (Figure 1). Even trying to acquire them with a scanner or with a digital camera, after a manual recomposing of the sherds, gaps and fracture lines will remain visible in the output because of an incorrect coincidence of the fragments or for the lost of the emulsion. Moreover, it is not advisable to further physically manipulate the fragments because of their extreme fragility.

The use of the glass plates in the Catania archive has been carried on, way after the introduction of celluloid support for photography. This is, strangely, a fortunate case because of the greater chemical stability of glass. The trouble with images on glass plates is instead in their fragility and in the occasional peeling off of the emulsion.



(a)



(b)

Figure 1. (a) Fragmented glass plate depicting a funerary painted urn (half of III century BC) from the excavations at Centuripe. (b) Overview of old town of Centuripe, on the right the Calvario hill.

When a plate breaks, moreover, the thin emulsion surface scratches and deforms itself especially in the proximity of the fracture. Even if plates are preserved in optimal conditions, tiny fragments and sherds are impossible to recover and gaps in the emulsion film are physically unrecoverable.

In order to solve this problem and to quicken the process of virtual restoring a large amount of fractured glass plates, in this paper we propose an automatic method for the restoration based on the use of image processing techniques. The algorithm reduces luminance artefacts originated by the interaction between the scanner light and the glass and then it performs an image registration using a roto-translation to align the different pieces. Finally, the algorithm fills missing pixel values using inpainting techniques.

Thanks to this methodology, with a synergic research work of experts in archaeology and image processing it will be possible to rescue this treasure of archaeological repertoires, otherwise lost, that represents an important part of the history of archaeological research of the Catania University.

The authors of the present paper have found few references in the open literature which are specific to the glass plate acquisition and restoration problem (STANCO et alii 2004). At least two different contexts exist the methods of which can be borrowed for the problem at hand: the problem of reconstruction of ancient collapsed wall paintings and mosaics (PAPAODYSSSEUS et alii 2002) and the alignment of adjacent picture tiles, also called mosaicking (CAPEK et alii 1999). In this contribution we adapt the method proposed in (STANCO et alii

2004) for the virtual restoration of fragmented photographic glass plates in Catania archive.

The rest of the paper is organized as follows: Section II summarizes the algorithm proposed in (STANCO et alii 2004), and Section III shows some experimental results. A Conclusions section ends the paper.



(a)



(b)

Figure 2. (a) Original fragmented glass negatives. (b) Restored image with use of inpainting algorithm.

## 2. THE ALGORITHM

The glass plates are acquired after a rough manual re-alignment of the fragments close to each other. It may happen that gaps between fragments in the final digital image are present. The goal of the method is to eliminate the gaps. In a first approximation fragments are rigid, hence only roto-translations could be used. Since some amount of local deformation, best results are obtained adopting some form of local averaging.

### Detection

The method starts detecting in the scanned digital image where the gaps are located. This is easy considering how the glass negatives are digitized. The areas without glass do not arrest the light, hence they originate areas that are much lighter than the rest of the image.

From the input image  $I$ , a new image  $I'$  where each pixel is labelled "white" if it is in the gap or "black" if it is outside the gap. This is obtained by performing a thresholding with threshold  $Tb_1$  very high.

The algorithm needs to know which fragment the gray pixels belong to. Local averaging of the BW image produces an intermediate class of gray pixels. These gray regions corresponds to the "borders" between fragments and are used in the successive steps.



(a)



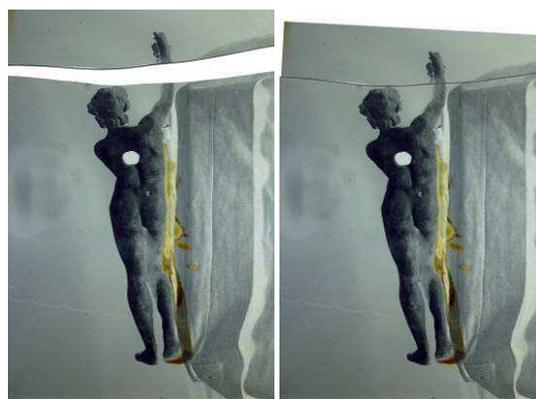
(b)

Figure 3. (a, b) Example of application of the algorithm on the fragmented glass plate with the Hellenistic funerary painted urn.

### Restoration

The successive phase of the algorithm tries to restore the fragmented glass plate photographs and proceeds in three steps. The first one reduces luminance problems; the second one performs a roto-translation to align the different pieces; the last one refines possible residual gaps.

**Step 1.** The acquisition process of the plate requires that a light beam is projected from the scanner toward the glass pane. This is a relatively thick plate and luminance artefacts close to the border of the glass support are common originating a "prism effect" and increasing the luminosity of the areas close to the gap. In this step a non linear filtering process that makes use of the labelling obtained in the detection phase eliminates such artefacts.



(a)

(b)

Figure 4. (a, b) Example of application of the algorithm on the fragmented glass plate depicting a bronze mirror handle in shape of naked boy (half of III century BC) from Centuripe.

**Step 2.** To obtain a good match between the pieces of the picture, it is possible to divide the registration-like problem in different parts: rotation and translation. The first copes with the estimation of the rotation angle between fragments.

The second part is the estimation of the displacement between the two pieces of the photographic glass plate. We use the well-known phase-correlation technique that is exploited in various motion estimation algorithms (ROOSMALEN 1999 and LUCCHESE et alii 2000) and that makes use of the properties of the Fourier transform.

**Step 3.** The image fragments are now very close one to each other. It could happen however that some parts of the fragments are lost before the scanning. For this reason an inpainting phase has to be carried out. When the gaps are tiny simple replication techniques have been proved effective, otherwise Poisson editing is a viable alternative (PEREZ et alii 2003). The image produced by this step is the final restored image.

## 3. EXPERIMENTAL RESULTS

The image in Figures 2, 3, 4, 5 and 6 are obtained using the approach described above. Figures 2(a), 3(a), 4(a), 5(a) and 6(a) report the original digitalized fragments. In Figures 2(b), 3(b), 4(b), 5(b) and 6(b) the obtained alignments are reported. In all of them the alignment obtained is very good.

Inpainting has not been carried out in Figures 2, 4, 5, and 6 because the responsible of the archive choose a more rigid philological approach and asked not to mask out the fractures of the plates. All the parameters adopted in our experiments are the

same that were suggested in (STANCO et alii 2004). However the procedure has been simplified and streamlined because of the huge amount of pictures to process.

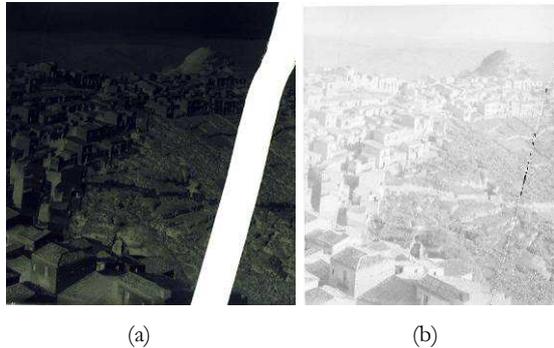


Figure 5. (a, b) Example of application of the algorithm on the fragmented glass plate depicting the overview of Centuripe..

We believe that the complete digitalization and alignment of the broken plates in Catania archive should be complete within a year. The resulting images will successively be made available via web.

We believe that with a synergic research work of experts in archaeology and image processing it will be possible to rescue this treasure of archaeological repertoires, otherwise lost, that represents an important part of the history of archaeological research of the Catania University.

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(a)



(b)

Figure 6. (a, b) Example of application of the algorithm on the fragmented glass plate depicting the Corinthian columns of the scene of the Hellenistic - Early Roman theatre of Taormina (Catania, Sicily).