# Range image binarization: Applications to wooden stamps analysis

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## ABSTRACT

This paper deals with the analysis of ancient wooden stamps. The aim is to extract a binary image from the stamp. This image must be the closer to the image produced by inking and using a printing press with the stamps. A range image based method is proposed to extract a stamped image from the stamps. The range image acquisition from a 3D laser scanner is presented. Pre-filtering for range image enhancement is detailed. The range image binarization method is based on an adaptative thresholding. Few simple processes applied on the range image enable a final binarized image computing. The proposed method provides here a very efficient way to perform "virtual" stampings with ancient wooden stamps.

**Keywords:** range image, binarization, 3D acquisition, local thresholding, stamps.

## 1. INTRODUCTION

The Troyes's Municipal Library is rich in old documents and books series (years between 1500 to 1900) among the most important in French provincial libraries. So, it takes care of a collection of 150 000 books, including 1700 medieval manuscripts, 700 incunabula, 2500 hawking booklets from "Bibliothèque bleue" serie but also about 800 graven wooden stamps used to illustrate those documents. This richness heritage led the Troyes's Municipal Library to join the Ancient Document Digitization national program of the French cultural department since 1998. As described in [1] one of the main problems involved in this program is to develop software and image processing systems to allow efficient access to the documents. This is the ANITA project (ANalysis of ancient Images and sTAmps).

This paper is concerned by the analysis of ancient wooden stamps. The aim is to extract a binary image from the stamp. This image must be the closer to the image produced by inking and using a printing press with the stamps. Of course, inking the stamps is forbidden as they are ancient sole museum pieces. It is thus impossible to put any product on the stamp. A typical wooden stamp is presented on Figure 1.

Two approaches can be explored. The first one is to get a classical image of the stamp. The gray level of the pixel represents in this case a quantity of illumination. There is not a direct correspondence between the gray level of the pixel and the geometry of the stamps. Previous works have shown that it is very difficult to obtain a good binary image from an illumination image [2]. It is an ill-posed problem. As in a stamp the printing zones are high elevation ones, the second approach is to work on a range image of the stamp. In a range image, the gray level is proportional to the elevation of the corresponding position. The geometry of the object can thus be assessed. We made the hypothesis that, from this geometry, simple processes can produce the wanted binary image.

This paper is organized as follows. Second section describes the acquisition system based on a 3D laser scanner. The range image pre-filtering and binarization are described in section 3. A conclusion and some perspectives are given in section 4.

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Figure 1 – Wooden Stamp

## 2. RANGE IMAGE ACQUISITION

The range images acquisitions have been realized by following a method described by Diou & al. [3]. The range images of the stamps are acquired using a non-contact optical sensor based on laser triangulation [4] to determine depth of the target points [5,6]. A sheet of laser light is projected onto the stamp's surface. The resulting 3D curve stripe is observed through two calibrated CCD cameras, and the 3D positions of the stripe points are calculated by triangulation. The two cameras are set so that the image of the stripe intersects each image row or column once, and the range information can be linked directly to one image coordinate. The range image acquisitions are realized on a 3D scanner [7]. The sensor system is mounted on a three-axis translation stage allowing the sensor to be moved along the x, y, and z axes. The object to be measured is placed on a table and the sensor is moved across the object. At each step, the CCD cameras acquire two images of the stripe projected onto the object surface being scanned, and the system computes the resulting depth information. Figure 2 shows an image of the 3D scanner.

The obtained range image is actually the plane projection of a 3-D surface, and consequently, the method of analysis we are presenting is comparable to classical 2-D image processing. The depth information in range images is gray-level coded and the range image is interpreted as a 2D image [8]. An example of such a range image is shown in Figure 3; where the z axis is also gray-level.

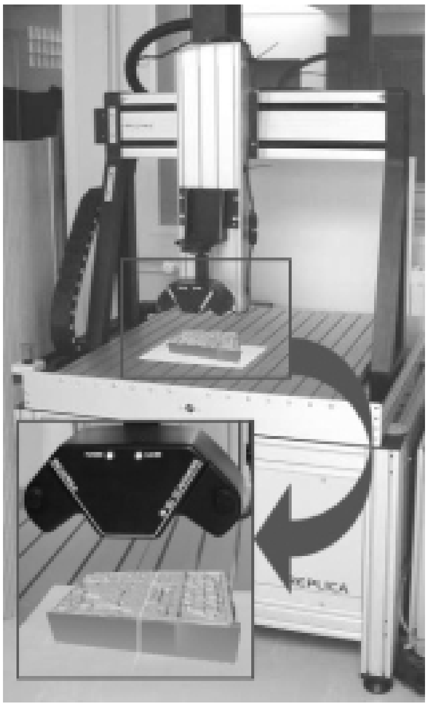


Figure 2 – 3D Scanner

Figure 3 – Range image of a stamp

## 3. PROCESSING

### 3.1. Pre-filtering

The 3D scanner can produce voids or spikes. Voids appear when no measure has been performed. Spikes are pixels containing aberrant values. Spikes appear when depth measurement has been mistaken. For example, highly specular zones often lead to unwanted reflexions that provoke spikes or voids. A pre-filtering is so necessary to prepare the rough range image for binarization. Voids are replaced with data values linearly interpolated from neighboring points. A first direction is interpolated followed by the second one. The second sweep is only used where complete lines of data are missing. Spikes are removed by applying a median filter. In our application, we chose a [3 x 3] window for the median computation. The advantage of median filtering over average filtering is that spikes are removed with less likelihood of rounding sharp edges that have to be preserved in the range image.

The scanned stamps surfaces are most of the time tilted. In order to ease the binarization step, the range image has to be adjusted. The mean plane of the range image is computed by a least square minimization method. The mean plane is then subtracted to the range image. An offset is then added to the image in order to obtain only positive values.

The pre-filtering process is schematically represented on figure 4.

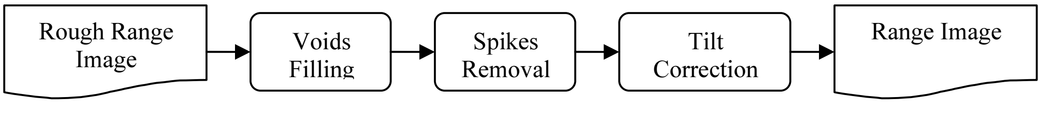



Figure 4: Pre-filtering process

### 3.2 Binarization

The binarization is computed in order to simulate the printing process with black ink on white pages. As in a stamp, the printing zones are high elevation ones; the high gray level pixels in the range images have to be binarized as black (pixel = 0). The non-printing zones have therefore to be binarized as white (pixel = 1).

We first used the Niblack's algorithm to binarize range images [9]. The principle is to adapt the threshold over the image. The threshold is determined from the local mean and the local standard deviation, computed on a restricted neighbourhood for each pixel.

Let us define :

| | |
|---|---|
| m: | the local mean computed on a [w x w] neighbourhood |
| s: | the local standard deviation computed on a [w x w] neighbourhood |
| t: | the local threshold for each pixel |
| k: | a user defined parameter |

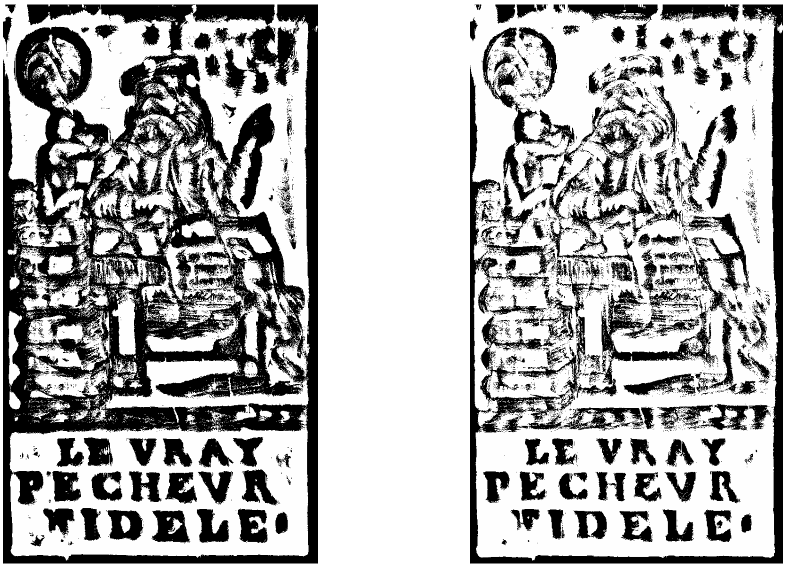
The binarization is computed as follows :

```
For each pixel of the range image Do
        If pixel > t = m+k.s then pixel = 0
                Else pixel = 1
        End if
End Do
```

The parameters are w, the width of the neighbourhood and k the user defined parameter. In our application, we used w=51 in order to follow the slow variation of the image. The “k” parameter allows adjusting the local thresholding. The more k is negative; the closer to the base of the fast variations of the image is the threshold. On the other hand the more k is positive; the closer to the top of the fast variations of the image is the threshold. Figure 5 shows an example of the binarized image computed with the presented method.


Figure 5: binarized image with t=m+k.s and k=0.3

By modifying the “k” parameter, it is possible to simulate the inking and printing process at various conditions (ink quantity, paper quality or humidity, ink fluidity, exerted pressure ...). Figures 6a) and 6b) show the same range image as used in Figure 4, binarized for k= 0.1 and 0.5. We can notice the “inking” variations produced by the “k” value modification.




a) k = 0.1 b) k = 0.5

Figure 6: k effect on binarization (t= m+ k.s)

However, this algorithm presents failures leading to artefacts. The algorithm leads to binarize low elevation zones when they present important deviations. It happens when there is a split or when there are small range peaks with fast variations in a low elevation zone. In these cases, the threshold remains low because of the low zone but some pixels greater than the threshold due to fast variations produce artefacts. Such artefacts are highlighted in figure 7 (near the hand and near the text "LE VRAY").

As figures 5 and 6 show, increasing k allows to partially eliminating such artefacts but the binarization quality decreases in high elevation zones. So we have to detect high elevation and low zones in order to adapt the threshold by increasing its value in low zones and remaining as previously described in high elevation ones.

To select high elevation and low zones, we compare the local mean “m” computed on a restricted neighbourhood to the mean “M” of the complete range image.

Then, the binarization algorithm becomes:

```
For each pixel of the range image Do
        If m >M Then t = m + k.s          (the neighbourhood is in a high elevation zone)
                Else t = M + k s          (M>m and the neighbourhood is in a low zone)
        End if

        If pixel > t Then pixel = 0
                Else pixel = 1
        End if
End Do
```

We can summarize the local threshold computing with the formula:

$$t = \max(M, m) + k.s$$

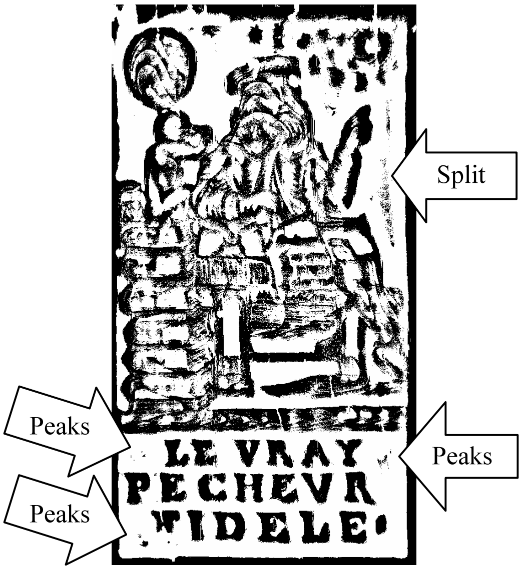



Figure 7: Example of artefacts

Figure 8 shows the binarized image computed with this last method and k=0.3. We can notice that the artefacts presented in Figure 7 have been removed and the binarization quality remains good in high elevation zones.

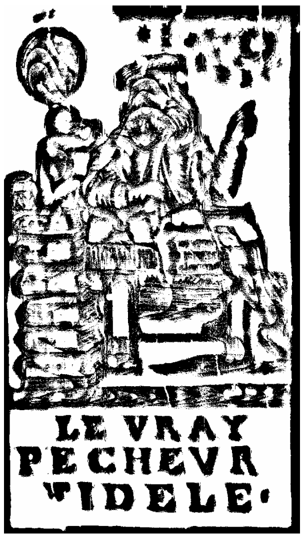



Figure 8: binarized image with $t = \max(M,m) + k.s$ and $k=0.3$

## 4. CONCLUSIONS

We have exposed a method for range image binarization applied to ancient wooden stamps analysis. The range image acquisition from a 3D laser scanner has been presented. Pre-filtering for range image enhancement has been detailed. The range image binarization method is based on an adaptative thresholding. Few simple processes applied on the range image enable a final binarized image computing. This binary image has to be very close to the printed image when the stamp is inked. The proposed stamp analysis method has been validated by comparing real stamped images to virtual ones. The experts (researchers in books history) are satisfied of the final black and white image. The proposed method provides here a very efficient way to perform "virtual" stampings with ancient wooden stamps.

The next step in the project is to apply the "virtual" stamping method to the 800 ancient wooden stamps of the Troyes's Municipal Library. We are working on the construction of a mobile 3D acquisition system prototype. This system will be based on laser triangulation and has to be as low-cost as possible. Future work concerns also the use of the range images in CAD/CAM environment to duplicate the ancient stamps. First results of manufacturing are very promising. The duplication will enable researchers in books history to better understand the stamping process by performing real inking on duplicated stamps.

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