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AN AUTOMATIC METHOD FOR DIGITIZING BATHYMETRIC MAPS

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***Abstract**: Automatic digitizing of bathymetric maps can be of great interest when archive provides these materials in printed or any other analogic format. As an extension of limit detection method for visual watermarks, it makes correct classification for the pixels of interest from the scanned image of the map. This means to identify (interactive) the watermarking limit of the object (in this case isobaths) and to save relative coordinates of sampling points in output file. The numerical values recorded in the output file represent the coordinates of each point and the depth value attached at isobaths. This data can then be used in any system that needs digital bathymetric information. The comparison between the image of the bathymetric map rebuilt from digitized data and the original image map demonstrates that they are virtually identical.*
***Keywords**: automatic digitization, bathymetric map, visual watermark.*

Introduction

The archived digital bathymetric maps are extremely important as any naval route relates to bathymetry. Moreover, a comparison between static, archive map and the real-time map (e.g. Bathymetric Sonar System) could detect changes of the seafloor topology but also military intrusions, when the information are correlated with other kind of data. In this reason an automatic system able to digitize bathymetric maps from analog formats (scanned maps) could be of large interest.

The proposed method of digitization assimilates the bathymetric isolines like a visual watermark that is overlapping the host image. Based on this assumption the specific methods are used to classify pixels of interest as watermark object. When the visual watermark limits are detected, the image of the watermark is defined and therefore could be processed in such a way that every isobath to be of one pixel width. Subsequently, the proper digitization proceeding can be now directly applied.

For a correct classification of the pixels of interest in a bathymetric map's image, which belongs to an object of watermark type (isobaths), it is necessary to identify at least one point of every isobath. An interactive process requests the operator to choose a point from every contour line and, starting with it, the lines are identified.

Then, on every defined point is traced a vertical profile where the algorithm based on 1st and 2nd image statistics order for a vector [1,4] is applied.

Analysis and pixels classification

To identify typical characteristics of visual watermarking type, it is analyzed the result obtained by applying tese statistics on the image using differential operators along the vertical alignment. Therefore, the following processes are performed directly on the image:

Arithmetic mean of R, G, and B calculated on three points on left and right of the current alignment [3,8] (*sSR, sSG, sSB* respectively *sDR, sDG* și *sDB*):

$$
\begin{aligned}
sSR_j &= \frac{1}{3}\sum_{k=j-1}^{j-3} R_k \\
sSG_j &= \frac{1}{3}\sum_{k=j-1}^{j-3} G_k \\
sSB_j &= \frac{1}{3}\sum_{k=j-1}^{j-3} B_k \\
sDR_j &= \frac{1}{3}\sum_{k=j+1}^{j+3} R_k \\
sDG_j &= \frac{1}{3}\sum_{k=j+1}^{j+3} G_k \\
sDB_j &= \frac{1}{3}\sum_{k=j+1}^{j+3} B_k, where \quad j \in (0+2, M-1
\end{aligned}
\qquad (1)
$$

Arithmetic mean of RGB processed on matrix of dimension 3x3 on left and right of the alignment (*sSm* and *sDm*):

$$
\begin{aligned}
sSm_{i,j} &= \frac{1}{9}\sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j-3}(R_{k,l}+G_{k,l}+B_{k,l}) \qquad (2) \\
sDm_{i,j} &= \frac{1}{9}\sum_{k=i-1}^{i+1}\sum_{l=j+1}^{j+3}(R_{k,l}+G_{k,l}+B_{k,l}), \\
&where \quad i \in (0,N),\, j \in (0+2, M-1)
\end{aligned}
$$

Weighted average of RGB on whole matrix *sM*:

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$$sM_{i,j} = \frac{1}{9}\sum_{k=i-1}^{i+1}\sum_{l=j-1}^{j+1}(R_{k,l} + G_{k,l} + B_{k,l}),$$
$$where \quad i \in (0, N),\ j \in (0, M) \tag{3}$$

The R, G and B differences computed on left and right matrixes (*sDifDR, sDifDG* and *sDifDB*):

$$sDifDR_i = sSR_i - sDR_i$$
$$sDifDG_i = sSG_i - sDG_i$$
$$sDifDB_i = sSB_i - sDB_i, where \quad i \in [0, N] \tag{4}$$

The R, G and B normalized differences computed on left and right arithmetic means of the alignment (*sDifSR, sDifSG* and *sDifSB*):

$$sDifSR_i = sDR_i - sSR_i$$
$$if\ sDR_i - sSR_i > 0, altfel\ sDifSR_i = 0$$
$$sDifSG_i = sDG_i - sSG_i$$
$$if\ sDG_i - sSG_i > 0, altfel\ sDifSG_i = 0$$
$$sDifSB_i = sDB_i - sSB_i$$
$$if\ sDB_i - sSB_i > 0, altfel\ sDifSB_i = 0,$$
$$where \quad i \in [0, N] \tag{5}$$

Not normalized R, G and B differences computed on left and right arithmetic means of the alignment (*sDifR, sDifG* and *sDifB*):

$$sDifSR_i = sDR_i - sSR_i$$
$$sDifSG_i = sDG_i - sSG_i$$
$$sDifSB_i = sDB_i - sSB_i$$
$$where \quad i \in [0, N] \tag{6}$$

Statistical analysis of the picture

There are chosen statistical characteristics of the image, computed based on the parameters described above, in graphical format. An important part of numerical representation of 1st and 2nd order gradients is taken from the analytical and graphical representation of the potential field [1,3].

Weighted average of three contiguous pixels from the left of the alignment *mSR3*, *mSG3* and *mSB3:*

$$mSR3_i = \frac{1}{3}\sum_{k=i-1}^{i+1} sSR_k$$
$$mSG3_i = \frac{1}{3}\sum_{k=i-1}^{i+1} sSG_k$$
$$mSB3_i = \frac{1}{3}\sum_{k=i-1}^{i+1} sSB_k, where \quad i \in (0, N) \tag{7}$$

Weighted average of seven contiguous pixels of *sVSm*, *sVDm* and *sVM:*

$$sVSm_i = \frac{1}{7}\sum_{k=i-3}^{i+3} sSm_k$$
$$sVDm_i = \frac{1}{7}\sum_{k=i-3}^{i+3} sDm_k$$
$$sVM_i = \frac{1}{7}\sum_{k=i-3}^{i+3} sM_k,$$
$$where \quad i \in (0+2, N-2) \tag{8}$$

Weighted average on three lines for *sDifR, sDifG* and *sDifB* : *R3Dr_Stg* , *G3Dr_Stg* respectively *B3Dr_Stg:*

$$R3Dr\_Stg_i = \frac{1}{3}\sum_{k=i-1}^{i+1}(sDifDR_k - sDifSR_k)$$
$$G3Dr\_Stg_i = \frac{1}{3}\sum_{k=i-1}^{i+1}(sDifDG_k - sDifSG_k$$
$$B3Dr\_Stg_i = \frac{1}{3}\sum_{k=i-1}^{i+1}(sDifDB_k - sDifSB_k),$$
$$where \quad i \in (0, N) \tag{9}$$

Weighted average of left and right RGB differences *R3Dr-Stg* , *G3Dr-Stg* and *B3Dr-Stg:*

$$DifRGB_i = \frac{1}{3}\sum_{k=i-1}^{i+1}\begin{matrix}(R3Dr\_Stg_i + \\ + G3Dr\_Stg_i + \\ + B3Dr\_Stg_i)\end{matrix} \tag{10}$$
$$where \quad i \in (0, N)$$

Weighted average of the RGB gradient *sSm* and *sDm:*

$$GrdSD_i = sign(sSm_i - sDm_i) *$$
$$* \sqrt{\left|sSm_i^{\ 2} - sDm_i^{\ 2}\right|}. \tag{11}$$

The sequence for watermark classification

The border of the watermark is detected when the pixels of the image which incorporates it are classified as watermark image. The recurrent algorithm [1,3] is:

a. The pixel is classified by default as extern watermark *Wext*; I_w
b. Is tested *DifRGB$_i$*, if $|\,DifRGB_i\,| < ctR$, where *ctR=12* is a threshold, constant value, related to watermark image contrast the process is continued
c. If the weighted average *GrdSD$_i$* is in the extended range from *pljm* to *pljM* (24-117 for our bathymetric watermark, values that can be experimental detected) then the

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pixel is inside of the watermark, or in other words, it belongs to the isobath

d. The detected curve is framed by two limits, the left and right of the analyzed point. Digitization should be done using a single limit, otherwise we get two values for a single measuring point. To solve this problem a new profile is analyzed on X axe direction, as a new algorithm iteration of the classification to save only one side of the curve.

Processing Results

Starting with the original bathymetric map image (presented in figure 1) the algorithm is applied following the sequence previously described.

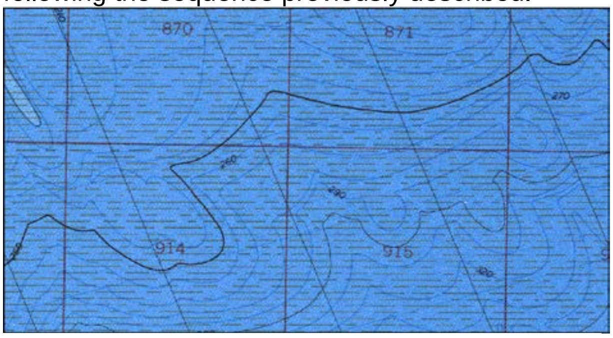

Figure 1. Original bathymetric map – scanned image.

The specified watermark is detected and classified, a primary image of the extracted isobaths (assimilates as watermark) is produced (figure 2).

The outline values of the watermark were selected that the right limit of the reference curve to be used for digitization.

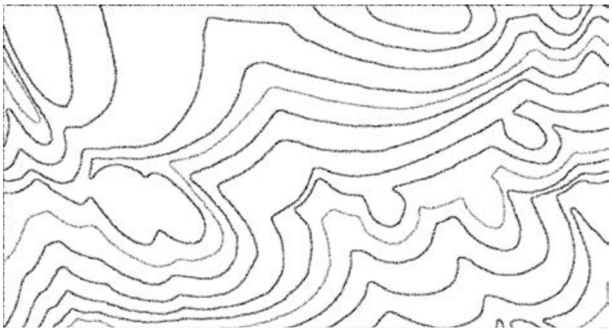
Figure 2. Roughly isobaths extracted from the map image.

It results several points representing watermark limit that are graphically represented in figure 3.


Figure 3. Digital bathymetric map

Conclusion

Using the detection of visual watermarking limit as a method of isobaths digitization from scanned images offers excellent results for archived bathymetric maps. For a better comparison, the digitized bathymetric map was overlapped on the original image, in figure 4.

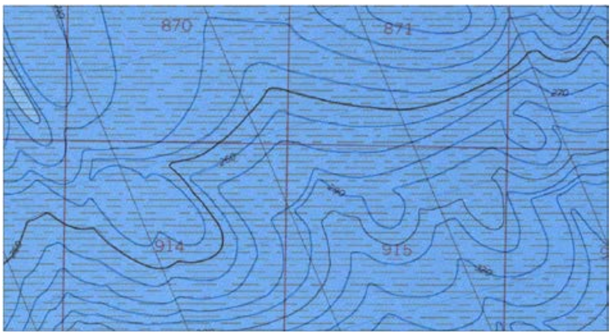

Figure 4. Digital map overlapped on original bathymetric map image

The present research has digitized noisy map images, with a specific texture, but the result of the process has no errors. This example demonstrates also a good robustness of the method, when the curves are not homogenous in a noisy host image.

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