ANALYTICAL PHOTOGRAPHIC RECTIFICATION THE WALLED CITY OF CITTADELLA (Padua, Italy).

Francesco Guerra - Camillo Trevisan
Centro Interdipartimentale di Cartografia e Fotogrammetria - IUAV - Venezia - Italy

The need to identify the most efficient methods and instruments for the survey of the walled city of Cittadella prompted us to examine those systems which have the capacity to analyze wall texture. In the first phase photographic rectification emerged as the best solution, although the cost is unbearable when using orthoprojectors for differential rectificators or automatic computer assisted rectificators. Manual photographic rectification, on the other hand, generally does not guarantee a sufficient degree of precision nor a homogeneity of results. Starting with these considerations and a knowledge of applicable developments in computer graphics, we have finalized our analysis of alternative processes to traditional photographic rectification, keeping financial concerns in mind. In the course of this research analytical methods were tested using commercial software and PC hardware.
Within the scope of this survey is an examination of three distinct procedures:
a)methods of furnishing an image of the photographic or raster type;
b)methods which anticipate a large manual intervention in the phase of digitalization;
c)methods of automatic vectorialization;

Introduction

This report outlines the initial findings of an investigation of those survey methods applicable to a study of wall texture by means of automatic rectification.
The study began as part of a project designed to identify the best available survey technique for the city of Cittadella.
Such research is linked to the article of Arch. di Thiene and of Dr. Baratin on the techniques of their experimental photogrammetric survey of Cittadella.
The survey of the walls of Cittadella consists of a field of complete experimentation regarding all those problems encountered when surveying wall texture. The specific results obtained in this particular case can, however, be made generally applicable to the survey of any wall texture.
In order to obtain a final and complete design, any survey of wall texture can not be limited to considerations of aesthetic character alone, but must also include analysis of building techniques. The study of wall texture includes, in fact, a combination of information regarding:
-the disposition and dislocation of holes (doors, windows, support holes, niches...)
-the geometric characteristics of various construction materials (bricks, stone, wood, connecting rods, tie rods, braces, mortar...)
-a few phenomena of decay (stress fractures, humidity, chipping, vegetation...)
Such information is essential to historical, statical, physic, and chemical analyses. The problematic character of a survey of texture can best be resolved by means of the traditional photogrammetric survey.
The traditional photogrammetric technique is, however, extremely onerous in terms of time and money on account of the large number of elements which must be considered in this kind of restitution. These difficulties can be resolved if one considers applying the procedure of automatic rectification.
Such an approach is warranted considering that wall texture belonging to a structure has the intrinsic characteristic of appearing in such a way that, though endowed with quite significant features, it is similar to a plane. If the wall structure is such that it is significantly non planar it is always possible to subdivide it into portions ever smaller until finally these become similar to a plane.

Experimentation

For a complete evaluation of the viability of rectification we have taken into account methodological, qualitative, and metric aspects as well as those considerations of cost and time. In order to carry out the evaluation, diverse methodologies of rectification were performed on the same section of wall.
The first step of this process involved the identification of a set of targets on the surface of the restitution subject which are obtained through topographic or photogrammetric means. Such targets must be sufficient in number in order to permit not only a calculation of parameters of rectification but also to test that the segment of wall under

consideration is actually similar to a plane; this is, in fact, the condition necessary to carry out rectification. Whereas by means of the calculation of the eight parameters of rectification four control points are necessary, it is useful, to evaluate how far from a plane is the portion of wall under consideration, that the control points should be at least double (or more) and distributed in a uniform manner on the surface.On the zone of wall singled out for this test the following typologies of rectification were tested which seem to cover almost all the possibilities:

a)methods of furnishing an image of the photographic or raster type;
a1-analogical, manual, photographic rectification by means of a special enlarger;
a2-analytic rectification of the raster matrix obtained by means of a scanner;

b)methods which anticipate a large manual intervention in the phase of digitalization;
b1-manual digitalization on the non-rectified photograph and immediate rectification of vectors across appropriate programs that one interposes between the digitizer and the CAD programs.
b2-rectification in batch from the inside together with the vectors which constitute the design obtained through digitalization of a non-rectified photograph by means of the scanner.

c)methods of automatic vectorialization;
c1-vectorialization aided by a program of a non-rectified raster matrix and a successive rectification in batch;
c2-vectorialization aided by a program of the raster matrix already rectified;

The method a1 (analogic rectification) constitutes above all the simplest and most immediate resolution to the problem but presents few advantages:
-the result is analogical and then not editable through CAD programs
-it is not possible to strictly control either parameters of rectification (in effect it is not possible to carry out any compensation) or the rectification plane reference.
-it is not always possible to make a precise subdivision of the total plane surface in sub-area.
The method a2 (rectification of the raster matrix) has the advantage of following an analytic procedure permitting control of data by means of compensation. In addition, it is possible to combine parts of images obtained with different parameters of rectification and the best possible patchwork.
One obtains from this method of restitution a photographic quality which, however, in contrast to that obtained from the proceeding method a1, can be the foundation for successive vectorialization (see c2). The principal difficulty is connected to the dimension of the raster matrix, and then to the capacity of the computer memory and to times of calculation. The dimension depends on the average scale of the pixel and of the size in bit (the number of tones of grey or colors) of the same pixel, according to table A.
Both b methods use as input for the rectification the digitalization of the non-rectified photograph. The differences between the two methods are not a reflection on the metric precision but solely on the character of the work method: in fact, the same program (PhotoCAD) is used in these two options, interactive and batch.
The advantages consist of the possibility of restituting with precision only the most significant elements of the objects which are selected during the restitution. The elements in addition can have a graphic structure (in blocks, polylines, etc.) in a form which greatly facilitates the general editing phase, always necessary.
There is, however, the necessity of operating with competent and specialized personel and, depending upon the particular digitalization used, the amount of time necessary may be from five to ten times greater than that required for automatic rectification (method c).
The c methods seem, at first analysis, like the optimum procedure and therefore we have concentrated our study on these methods. The procedure, in fact, promises in part a degree of precision intrinsically larger than that of the b methods , in so far as it excludes the introduction of errors due to human intervention, as well as an enormously greater speed of restitution.
From the following test, however, we have learned that it is not possible to obtain the promised results both because programs of vectorialization endowed with algorithims of pattern recognition appropriate for architectural surveys are still not available at a low cost, and because the condition of the photograph greatly affects the final result of scanning.
The graphic results of the following test are presented in the pages which follow. The experiment was carried out using two different portions of masonry in order to test both details and the all result. We have tested diverse resolutions of scanning, diverse scales of photograms, diverse methods of vectorialization and diverse filtering options of image.

Conclusion

From our experiments we have deduced, after obtaining a rectification of wall texture which fulfills those requirements of architecture, design, and having a good metric precision and a minimized time of execution, that it is necessary to adopt a procedure which combines aspects of both methods b and c.
We maintain, in fact, that the construction of part of the restitution partially integrates the process of design of architecture not existing of a biunivocal relationship between this and the photograph. This lack of correspondence is due to the fact that no software can possess (at least it is currently an unpredictable development in the field of expert systems) the knowledge in the field of representation, which permits the association to a symbol of complex and built whole of architectonic elements.

In addition to this structural and practically insurmountable difficulty, exists another difficulty regarding the quality of the images (of the atmospheric condition at the moment of the shot, of the optical instruments used for the shot, the printing and the scanning) which affects the performance of the vectorialization program.
Here, then, it seems necessary to conduct a deeper investigation into the treatment of the image.
Such a study can be finalized upon the achievement of a modified raster matrix in which it will be easier to recognize the outlines of the forms.
In conclusion we maintain that, at the fore of great improvements of the present procedure in the direction as indicated, human intervention will always be necessary and in the editing of the raster, by means of great image area manipulation, and in the editing of vectorialized drawing, with precise and specific interventions.

Reference

Rosenfeld A. - Kak A. C., *Digital Picture Processing*, London, Academic Press, Inc., 1982
Slama C.C., *Manual of Photogrammetry*, Falls Church Va., American Society of Photogrammetry, fourth edition, 1980
Serra J., *Image Analysis and Mahematical Morphology*, London, Academic Press, 1988
Selvini A., *Principi di fotogrammetria*, Milano, Clup, 1988

Hardware used

IBM PS/2 mod 55
Compaq Deskpro 386/20e
Macintosh cx
Scanner ScanJet Plus HP
Printer Apple Laserwriter II NTX
Plotter Calcomp 1041
Digitizer Calcomp 9148
Kern DSR1

Software used

PhotoCAD for manual and batch rectification
AutoCAD for drawings
QTDXF for vectorialization
Adobe Photoshop and Adobe Digital Darkroom for image processing

TABLE A

Photography scale 1:100

DPI	One Pixel is real cm	N. of Pixel per real cm^2	KB/cm^2 photography 2 colors	16 colors	256 colors
300	0,85	1,18	1,744	6,975	13,950
150	1,69	0,59	0,436	1,744	3,488
75	3,39	0,295	0,109	0,436	0,872
40	6,35	0,157	0,031	0,124	0,248

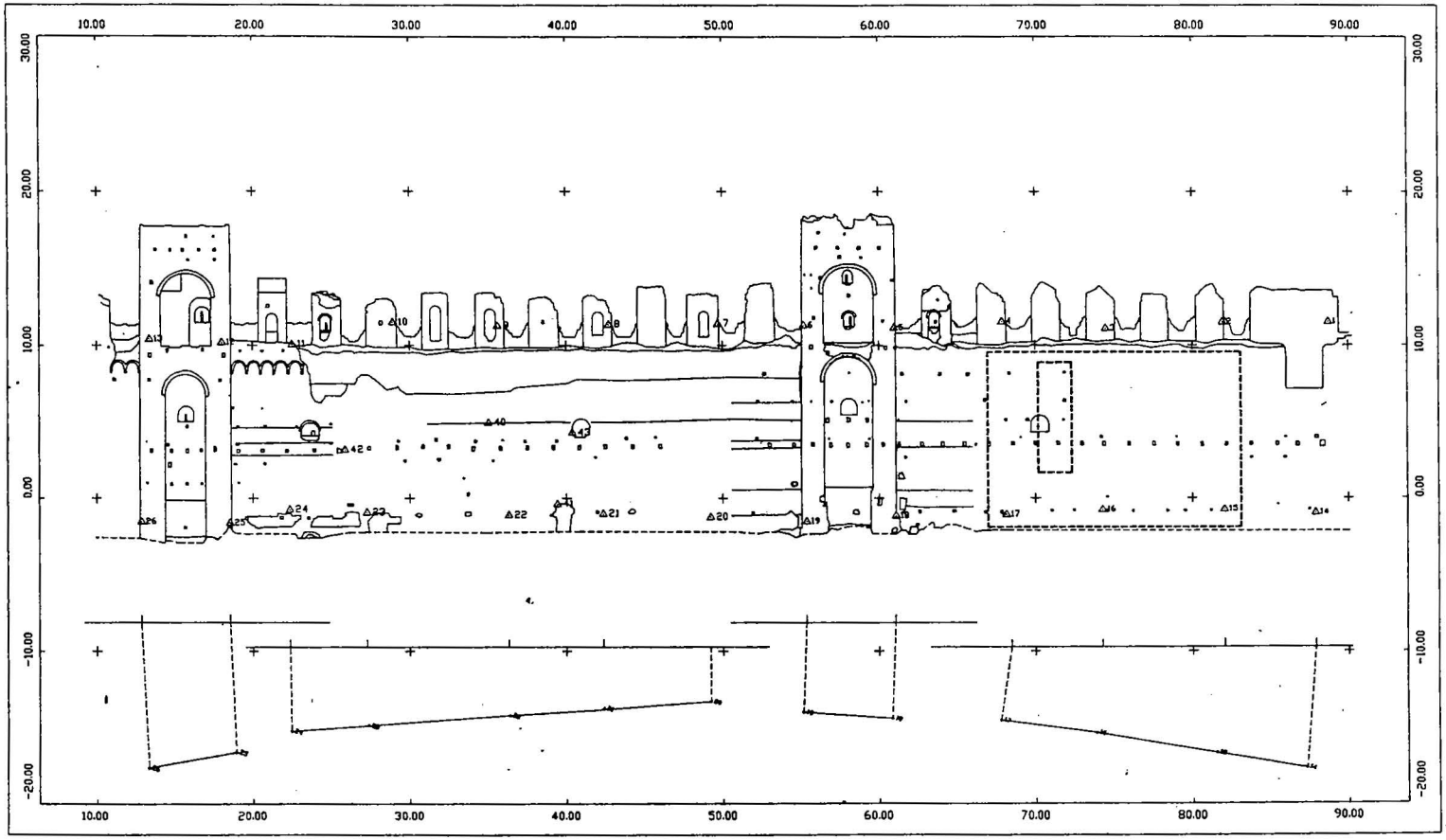

Fig. 1 - Front view of section of wall highlighting the parts under consideration for the experiments. For the general section we have used four topographic target points and fifteen points obtained through photogrammetric restitution; for the particular section six photogrammetric points.

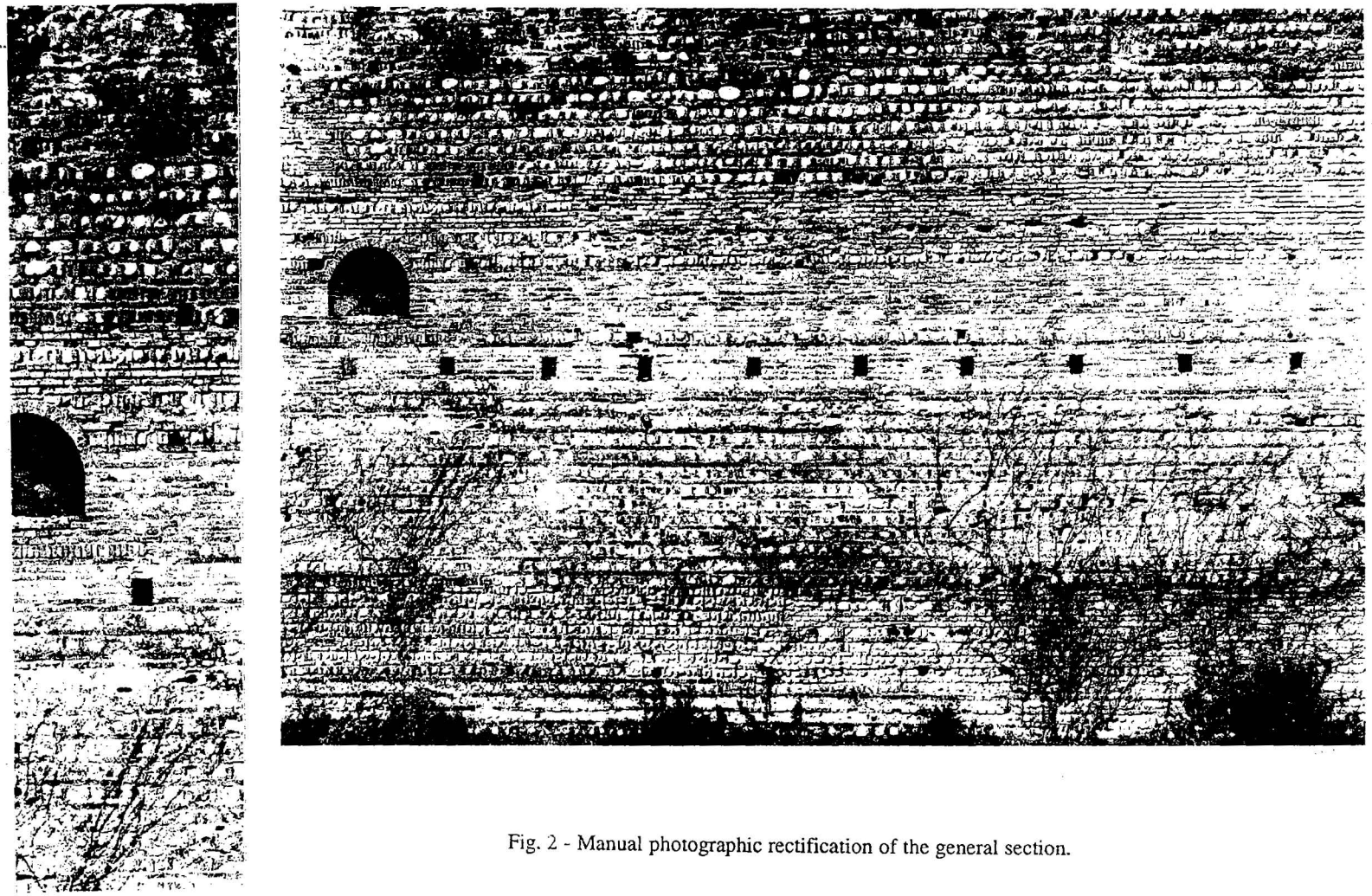

Fig. 2 - Manual photographic rectification of the general section.

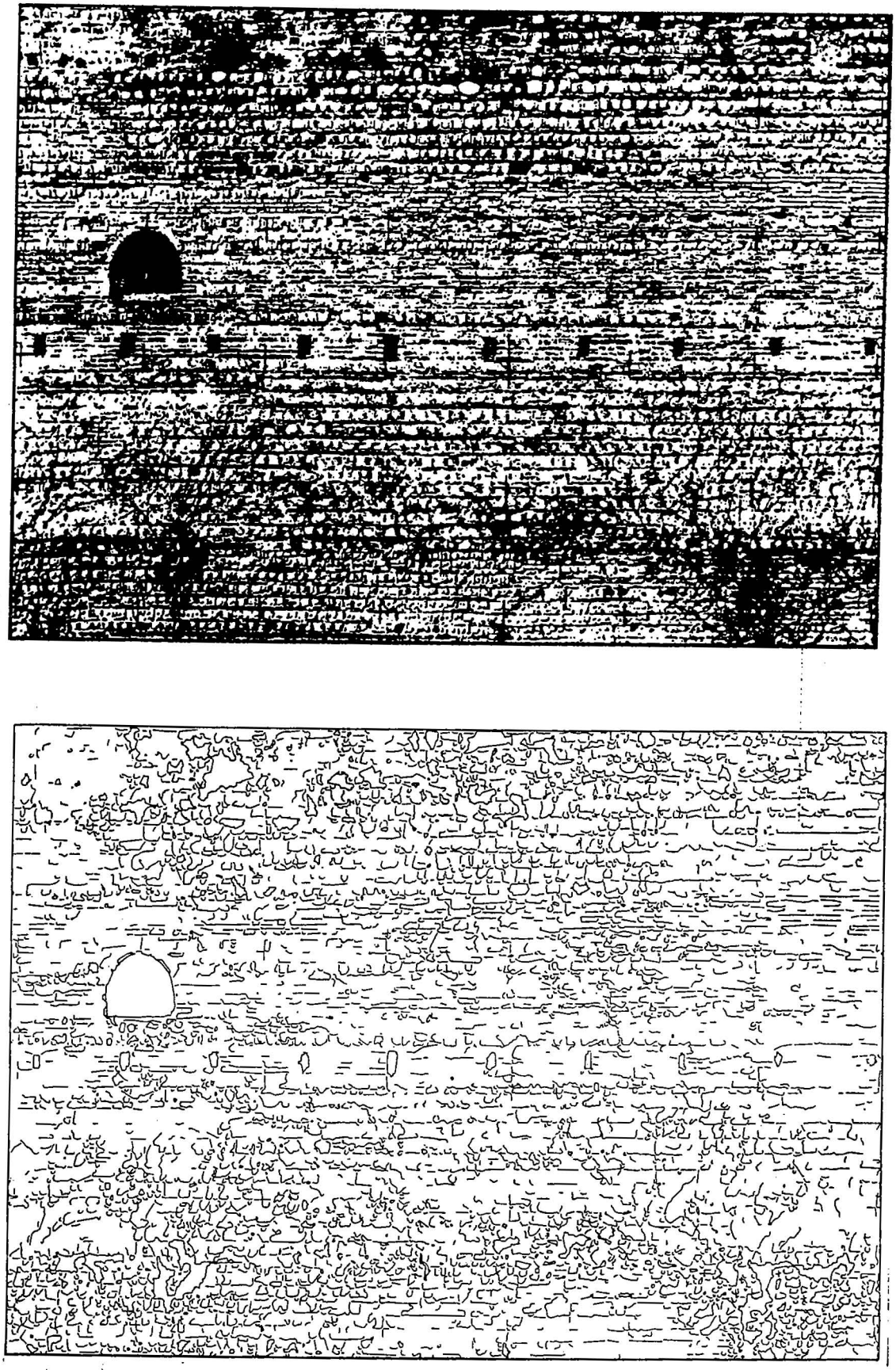

Fig. 3 - Print of one bit raster matrix (two colors) of general section.
Vectorialization of raster matrix at low level of detail.

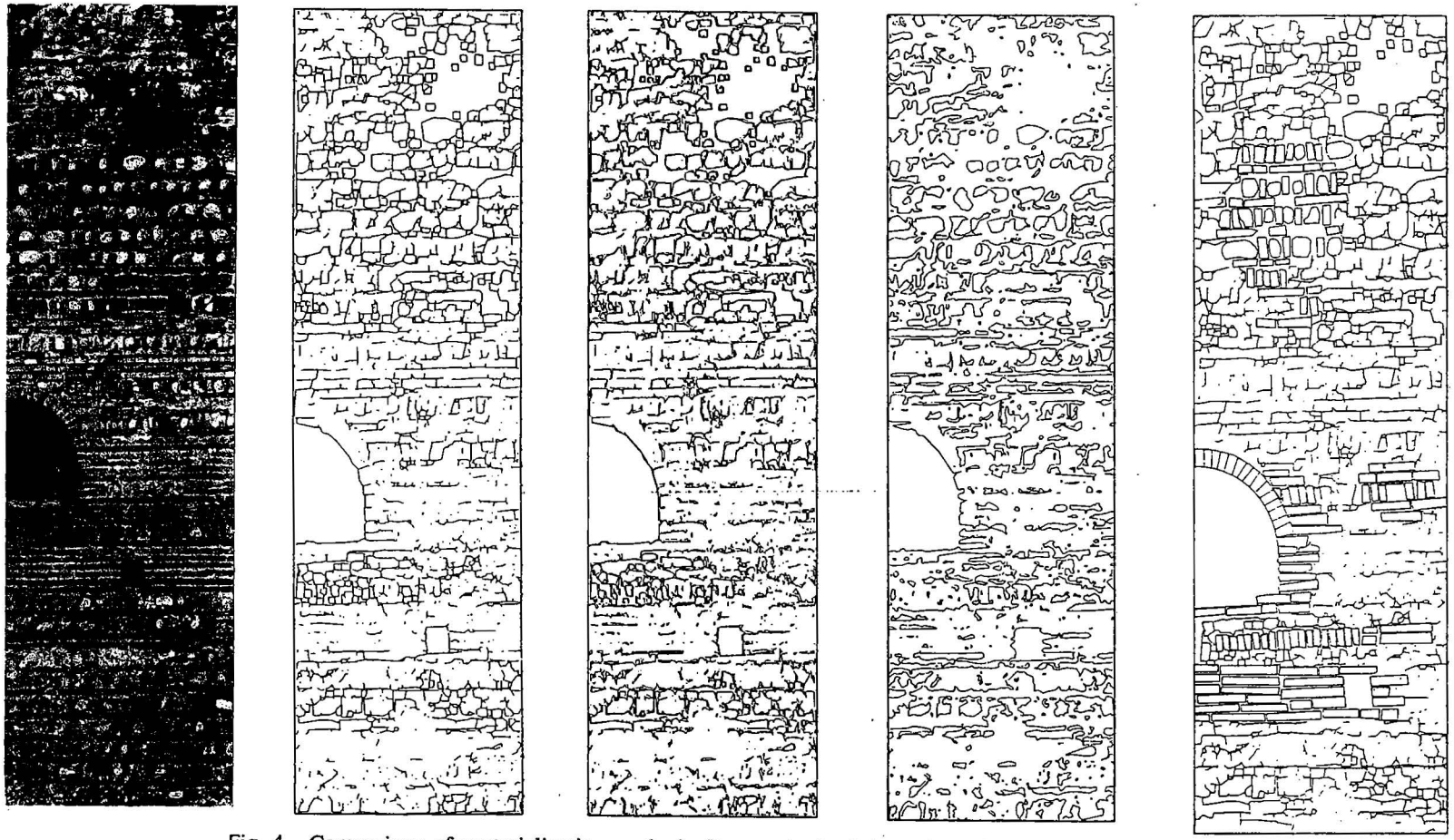

Fig. 4 - Comparison of vectorialization methods. B was obtained through an "outline" procedure (the contour of dark areas) at high resolution (300 DPI) and average accuracy. C was obtained trough "colouring" procedure (highlighting of light-dark areas), with average parameters of accuracy and thinning. D was obtained with "centerline" method, with average parameters. E represents a combination between manual digitalization and automatic rectification.

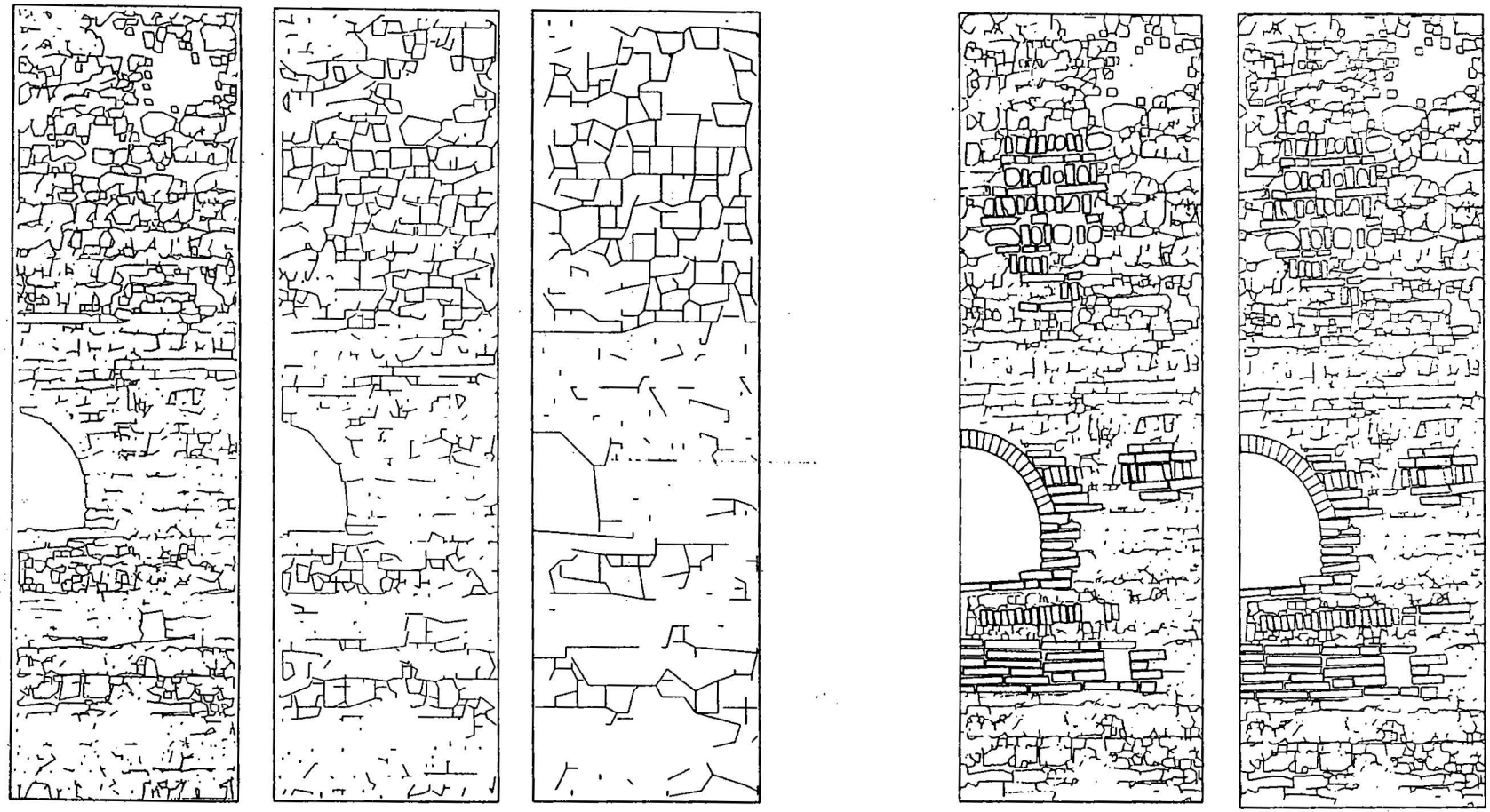

Fig. 5 - Section A. Comparison of various resolutions. A was obtained with outline method, 150 DPI of resolution (quite alike to 300 DPI); B was at 75 DPI and C at 40 DPI.
Section B. Combination between manual digitalization and automatic rectification. In the first figure is highlighted the digitized part.