TOOLS FOR DESIGNING CERAMIC TILINGS BASED ON HISTORICAL PATTERN STRUCTURING TECHNIQUES.

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ABSTRACT

The purpose of this communication is to present the work done in a research project on cataloguing and redesigning ceramic tilings, which is currently still ongoing.

With regard to cataloguing, the project has been stimulated by the need to recover the existing ceramic heritage. The information and documentation that historical ceramic tilings provide is to date still largely untapped in current tile design and production. The need for all the existing historical sources to be perfectly accessible, together with accurate references, represent the prerequisites to knowing and exploiting the resources that history and one's own experience can provide, as well as to reusing formal vocabularies, not as a mimesis of historical patterns, but as new designs with authoctonous references.

The structure of the study has been as follows:

- *Development of a database with graphics and data on the different existing products.*
- *Definition of a graphic tool for creating or altering designs.*
- *Development of a graphic tool for producing different compositions associated with a given product.*
- *Development of a tool for simulating the adopted solution in a given pre-set environment.*

1. INTRODUCTION

The application at issue has two basic objectives: one is to catalogue existing products and the other is to use the data provided by the catalogued products to redesign and reclassify new solutions.

With regard to the classification of existing products, this is based on the geometric structure of the pattern or visible figure associated with the product, as well as the various regular arrangements that the product can give rise to on application. Moreover, in principle, the different products are classified according to such varying features as: production date, production location, materials used in manufacturing, type of finish, number and names of colours, type of figure determining the design, etc., while having the opportunity to introduce any other important feature in the classification according to the particular needs of the user.

As far as redesign and reclassification are concerned, the application integrates the necessary transformations to research the new arrangements that a single product has, to somehow individualise feasible solutions for the future user with each product. The fact that it is the user himself who somehow "selects" his solution requires incorporating the visualisation of the compositional solution adopted in a pre-set environment in the application, i.e., the virtual image allows the client to see how the selected solution integrates in the relevant context.

The application thus consists of modules, by modules meaning the application's different areas of functionality: application environment, symmetry detection module, pattern reduction module, symmetry analysis module, new pattern generation module, database and image processing module.

The available functions in the application are typical standard application functions. The arrangement of these functions, within the context of the application is similar to that which appears in any general-purpose application, with a view to have the most intuitive possible environment. An intuitive environment means having a user-friendly application. However, knowing the working habits of the end user and the software packages currently being used can provide valuable information with regard to a possible restructuring of the application environment.

Each of the modules or blocks making up the application is described below to illustrate the purpose of the project. However, the paper will not go deeply into the theoretical concepts used, so as not to make the presentation too long. Only the basic concepts required for an understanding of the work will therefore be presented.

2. BACKGROUND

The initial considerations of the work undertaken concerned the complexity often involved in discovering the isometries present in a design, in order to identify the geometric scheme that develops the design, the need to compile substantial quantities of data to have material for analysis, and the fascination of symmetry group theory for developing new compositions. These considerations have led to assessing three different, albeit related issues: symmetry detection, recognition of similar shapes and generation of symmetry groups.

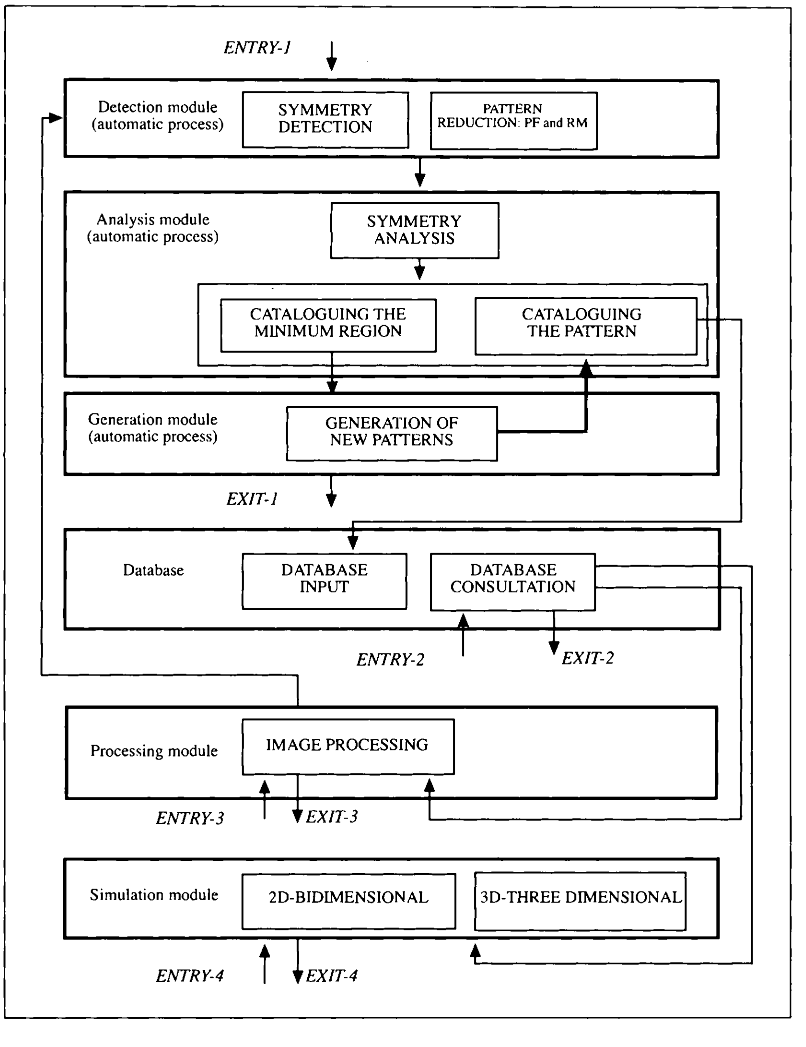
Symmetry detection has been widely studied since the 70s, when the development started of artificial vision. The following studies may be highlighted as chronological milestones in the development of symmetry detection, and form the basis of the proposed automatic symmetry detection in this study. Zahn and Roskies (1972) developed a method of plane closed curve analysis and synthesis using Fourier descriptors, so that rotation and axial symmetry were directly related to simple properties of these descriptors. Wolter and co-workers (1978) presented symmetry-detecting algorithms for polygons and point sets. Atallah (1985) developed an algorithm for detecting symmetry axes of flat figures (n points, segments, circles, ellipses, etc.). Highnam (1987) proposed an algorithm for locating the symmetry axes of a flat set of points as well as an algorithm for finding rotation symmetries. Eades (1988) compiled the available information on algorithms to detect the symmetries of geometric objects. Alt and co-workers (1988) considered the problem of calculating isometries (rotation, translation and reflection). Marola (1989) determined an algorithm for finding all the symmetry axes of flat images for digital images and planar curves. Llados and co-workers (1997) developed an algorithm for detecting the rotational symmetries of shapes defined by their polygonal contour and presented a modification of the same algorithm for detecting reflection symmetries. Kiryati and Gofman (1998) studied the detection of reflection symmetries in digital images. Dinggang and co-workers (1999) presented a method for detecting reflection symmetries and digital image rotation symmetries. And finally, Sun and Si (1999) presented an algorithm for detecting reflection symmetries by using the original digital image and image gradient data.

All these studies detect and determine the rotation symmetries and reflection symmetries of a certain image. However, an isolated image is involved in every case, i.e., they determine the isometries that make up the point symmetry group of the analysed image. In no case do they consider an analysis of the isometries making up the plane symmetry group. In view of this fact, considering that we are working with flat images containing a repetition, it is important and necessary to know the point symmetry group of the various shapes comprised in the design, but this is not decisive to determining the isometries of the whole design. Therefore, existing algorithms that detect isometries (rotation and reflection) of isolated shapes were used in this study to develop a method for determining which plane symmetry group has an analysed design, in other words, listing the isometries making up the plane symmetry group.

Other issues relating to symmetry detection are as follows: shape orientation, recognition of similar shapes and shape reconstruction. These are vital to the present proposal in order to be able to distinguish identical shapes in a design and be able to determine the various orientations in which a shape could be found in the design. Numerous studies in the literature have served as the basis for this study, of which the following are particularly noteworthy. Leou and Tsai (1987) determined an algorithm for analysing the rotation symmetry and orientation of a closed curve shape, by determining shape orientation after verifying curve rotation symmetry order. Tsai and Chou (1991) studied the automatic detection of the main axes of given shapes with known symmetry properties, in such a way as to use the symmetry axes to define shape orientation. Lin and co-workers (1992) were interested in detecting the orientation of symmetrical shapes rotationally, proposing specific shape points which enabled detecting symmetrical shape orientation rotationally (cyclic and dihedral). Zabrodsky and co-workers (1995) attempted to determine the degree of symmetry of a shape to be able to reconstruct hidden or blurred shapes. Kauppinen and co-workers (1995) focused their study on shape recognition, based on Fourier descriptors. Stein (1996) raised the issue of detecting and organising sets with similar perceptual contents using perceptual organisation criteria such as symmetry proximity, parallelism and closure, attempting to determine the difference between highly similar objects with different geometric properties.

And as the final basic feature of the present study, there is the widely studied symmetry group theory, the key reference study being the work by Grünbaum and Shephard (1987). Also noteworthy in the specific field of plane symmetry groups is the work by Schattschneider (1978), with a highly refined theoretical approach subsequently used by Abas and Salman (1992) to develop a computer application.

3. APPLICATION SCHEME



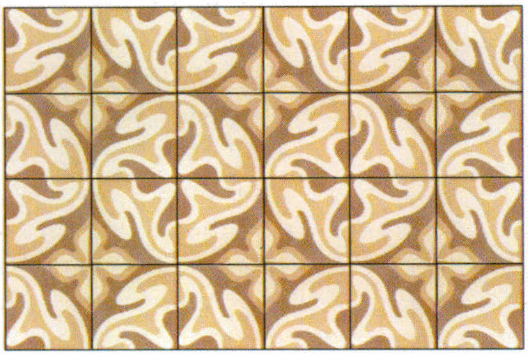


Figure 1.

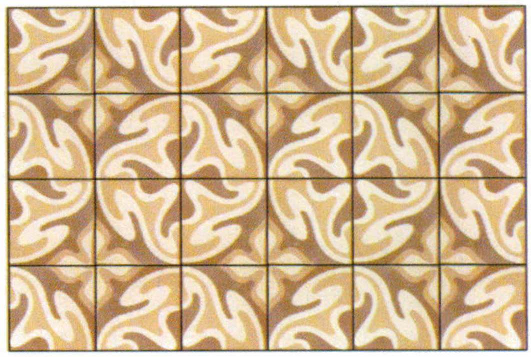


Figure 2.

4. DESCRIPTION OF THE VARIOUS MODULES

The various modules are briefly described below, indicating the following features: entering the module, process in the module, exiting and connection with the other modules. The modules are described using a pressed tile as an example, on which the various stages that unfold are graphically expressed.

4.1.- SYMMETRY DETECTION MODULE

This module is designed to automatically detect the isometries that each and every different elementary shape making up the design has. The purpose is to establish the basic geometric structure forming the design.

ENTERING the module. The entry datum will always be a bit map file containing the flat image of a design (Figure 1).

PROCESS in the module.

1.- Characterisation of formal units.

This process is designed to replace elementary shapes by points with all their characteristics. An elementary shape is taken to be the shape made up of closed contours with a certain chromatic unity. A series of determining characteristics is associated with each elementary shape making up the design.

The characteristics of each elementary shape are defined by:

- Contour determining curves
- Centroid coordinates (x,y)
- Orientation of the main direction
- Direction and number "n" of superimpositions by rotation
- Direction and number "m" of superimpositions by reflection
- Chromatic attribute

Patterns	Contour determining curves	Centroide coordinates	Orientation of the main direction	Number of superimpositions by rotation	Number of superimpositions by reflection	Cromatic attribute
Shape 1				1	1	White
Shape 2				1	0	White
Shape 3				1	0	White
Shape 4				1	1	Brown
Shape 5				1	0	Brown
Shape 6				1	0	Black
Shape 7				1	0	Black

Table 1.

Seven different shapes can be extracted from the design given as an example, whose characteristics are detailed in Table 1.

On determining the formal characteristics of each shape in the design, the shapes can be substituted by points to produce a first geometric scheme of the analysed design. Each of the seven shapes will be represented by a point located in the shape centroid and an orientation corresponding to the main direction of the shape. Figure 2 presents a superimposition of the seven shapes, together with the points and orientations that will subsequently replace each shape.

2. Formation of the point grids

The various grids are found by selecting the centroids with an identical characterisation, located in the plane according to their coordinates. Each grid comprises a single elementary shape arranged according to various orientations. To illustrate this breakdown into different grids, Figure 3 presents a scheme of the points found on substituting each shape by a point and an orientation. Figure 4 shows the various grids obtained from this scheme on considering shapes with identical characteristics except for the orientation (identical shapes are involved with different orientations).

Each of the resulting grids has a specific arrangement criterion. If the distances existing between neighbouring points are considered as grid-defining parameters, a reticulation is found with a finite number of parameters (distances or vectors) and geometric properties (inter-vector angles), which structurally define the design. Thus, in each of the previously obtained grids, what is termed the fundamental parallelogram can be produced by joining the points with the same orientation, which is the parallelogram that covers the plane without leaving any gaps or producing any overlapping by displacement in the two directions marked by its sides. The fundamental parallelogram is the parallelogram determined by four points, aligned in pairs, with the two minimum possible distances between them. Figure 5 shows the various reticulations of each grid, which determine the fundamental parallelogram.

Each fundamental parallelogram contains inside it and/or at its sides a concrete number of equal shapes, however with differing orientations with regard to

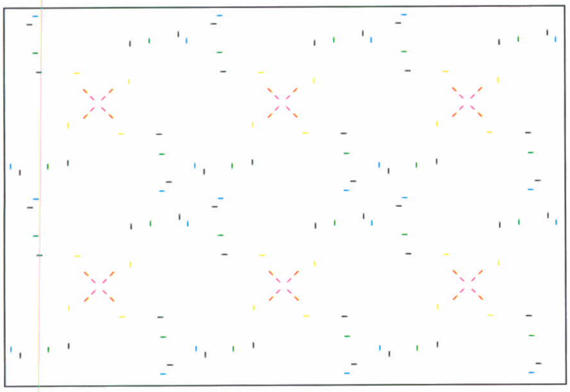


Figure 3.

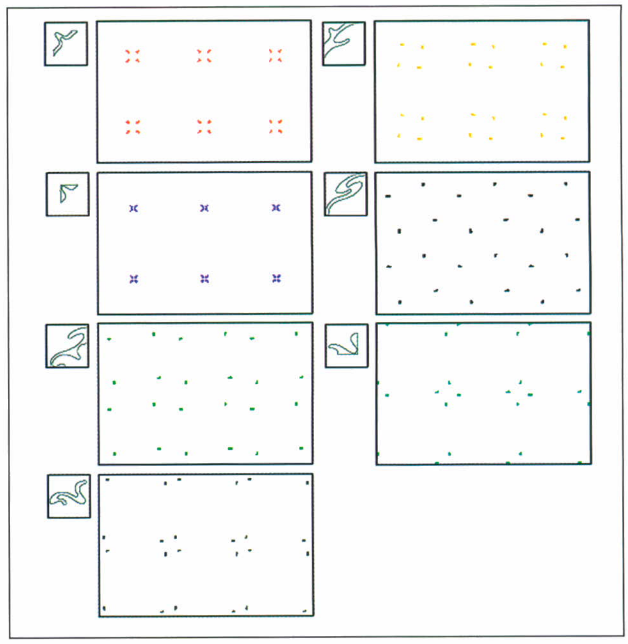


Figure 4.

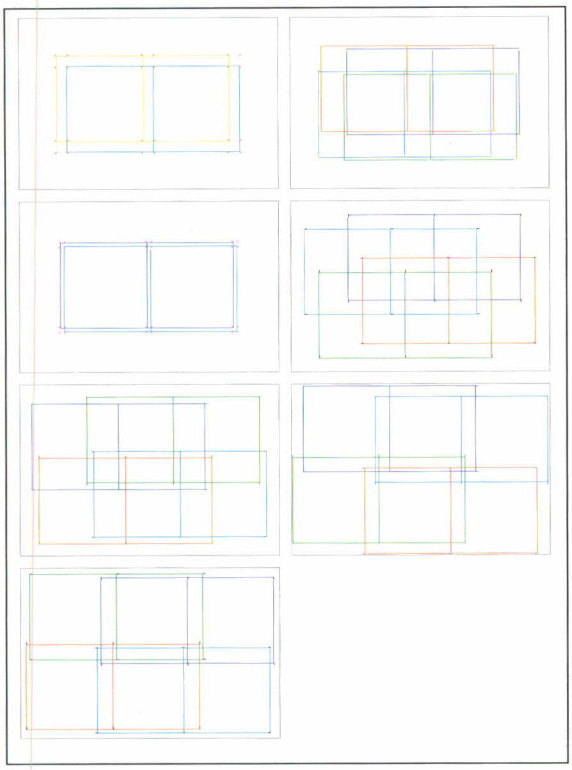


Figure 5.

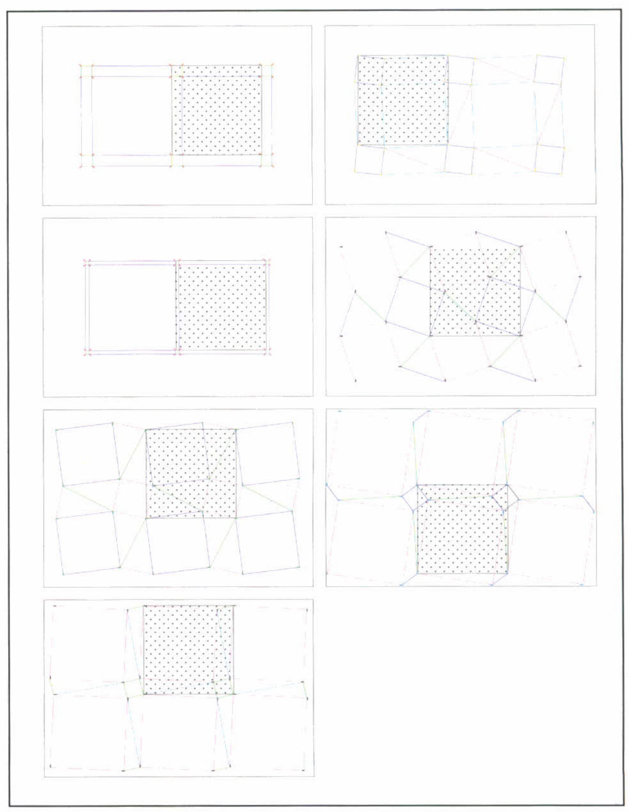


Figure 6.

the shape that determined the fundamental parallelogram. The fundamental parallelogram will never contain inside it a shape with the same orientation as the shape that determined the parallelogram. Similarly, certain parameters will be repeated in the arrangement criterion, i.e., there will be certain distances between the grid points, which are identical, and in some cases they will be determinative when it comes to fixing a plane symmetry group with an analysed design. Figure 6 presents the image of each grid, showing the fundamental parallelogram, internal points and parameters of each grid (identical parameters are presented in the graphic by identical colours.

To establish which grid really determines the plane symmetry group of the analysed design, two features need to be considered:

1.- If, as is usually the case, there are different point symmetry groups in the various design shapes, the cataloguing should be initiated considering the grids associated with shapes having a less restrictive point symmetry group, i.e., those shapes whose point symmetry group has a lower order (the order of a symmetry group is the number of isometries contained by the group). The more restrictive shapes will be those with a high order, e.g., a group with a D1 dihedral symmetry (order 2) is more restrictive than the C1 cyclic symmetry group (order 1). When there is an equality of orders, as for example occurs with C2 (order 2) and D1 (order 2), it suffices to consider any one of these, catalogue it and extrapolate the resulting data.

2.- If there is a repetition of the design, the fundamental parallelogram containing the greatest distances between the points with the same orientation will determine the fundamental parallelogram of the whole design. Only this parallelogram therefore needs to be analysed, catalogued, and subsequently subjected to the relevant verifications to check whether the introduction of the other shapes validate the cataloguing found. If there is an equal distance between points with the same orientation in the various grids, i.e., if the dimension of the parallelogram is identical whatever the grid considered, it suffices to consider any one of these, catalogue it and extrapolate the resulting data.

In the example at issue, there are two types of point symmetries in the different grids: C1 and D1, so that we can take the case of a grid with C1 shapes, observing (Figure 6 - dotted areas) that the five grids corresponding to this type of point symmetry group have identical fundamental parallelograms in dimension and shape. It therefore suffices to take either of these, perform the cataloguing and subsequently verify that the cataloguing obtained is valid for the whole grid design.

EXITING the module. There are two types of exit documents: the design file, which may or may not have the graphic indication of the fundamental parallelogram and/or of the points characterising each elementary shape and the fundamental parallelogram file, which may or may not have the graphic indication of the minimum region and/or of the points characterising each elementary shape.

CONNECTION with other modules. Previous module: Image processing. Following module: Symmetry analysis.

4.2.- ANALYSIS MODULE

To catalogue a pattern and assign it a plane symmetry group, it is first necessary to study the isometries of the pattern and subsequently catalogue it by analysing the isometries. However, the application should enable generating new patterns by taking a certain minimum region as a base and hence requires determining the isometries of this minimum region to establish the possible patterns to be generated. Symmetry detection should be automatically run by the application, as it is clear that it could initially be complicated for the user to detect the different symmetries that structurally characterise the relevant design.

ENTERING the module. The entry datum will be the exit document of the detection module, that is: the fundamental parallelogram identified according to the points characterising each elementary shape of which it is made up.

PROCESS in the module. There are two types of simultaneous or alternative processes: pattern cataloguing and minimum region cataloguing.

To proceed with design cataloguing, according to the plane symmetry group, the fundamental parallelogram defined in the foregoing module and the classification made by Grünbaum and Shephard (1987) of the different point patterns are taken as the basic references.

The exact values proposed for entering the cataloguing are as follows:

a.- Point symmetry group of the elementary shape defining the fundamental parallelogram.

b.- Number and type (rotation and/or reflection) of the different positions that the elementary shape has in the fundamental parallelogram.

c.- Geometric characteristics of the fundamental parallelogram. The shape of the fundamental parallelogram found will correspond to one of the following types: any parallelogram, parallelogram formed by isosceles triangles, parallelogram formed by equilateral triangles, any rectangle, square, any rhombus or rhombus formed by equilateral triangles, which are the different types of lattices that both Schattschneider (1978) and Abas and Salman (1992) distinguish.

d.- Number of elementary shapes located inside and at the sides of the fundamental parallelogram.

e.- Número de parámetros o distancias diferentes que existen entre las formas elementales semejantes que definen el paralelogramo fundamental.

f.- Relative orientations between the isometries of the elementary shape and the fundamental parallelogram.

Each of these six values eliminates a number of options relative to the possible plane symmetry group of the analysed design. Tables 2 and 3 detail the possible solutions.

Using Tables 2 and 3, cataloguing takes place automatically and uniquely of a design in which there is repetition according to its plane symmetry group, considering the above values a, b, c, d and e. The table indicates 11 cases in which verification of the plane symmetry group requires confirming the value of f, as there are two different groups. As an example of this check, case A and case I are set out below:

Case A: c1 / 2R / R / I0, L2 / DPP16 / 2 parameters/ possible groups PG and PM

- PG.- There is a sliding reflection through the midpoints of the opposite parallel sides of the fundamental parallelogram.
- PM.- There are two parallel reflections, at right angles to one side of the fundamental parallelogram, going through two points located, in respect of the vertices limiting the side to which they lie at right angles, at 1/4 the length of this side.

1	P	0	0	PP1	DPP8	3	P1	
	RD	0	0	PP1	DPP20	2	P1	
	R	0	0	PP1	DPP16	2	P1	
	RC	0	0	PP1	DPP20	2	P1	
	RE	0	0	PP1	DPP51	1	P1	
	C	0	0	PP1	DPP41	1	P1	
2R 0-R0	P							
	RD	0	2	PP5	DPP16	2	CM	
		1	0	PP5	DPP19	3	CM	
	R	0	2	PP2	DPP16	2	PG	A
				PP2	DPP41	1	PG	B
				PP3	DPP15	3	PM	
				PP3	DPP16	2	PM	A
				PP3	DPP41	1	PM	B
		1	0	PP2	DPP13	3	PG	
				PP2	DPP20	2	PG	
				PP2	DPP51	1	PG	
	RC	1	0	PP5	DPP16	2	CM	
				PP5	DPP19	3	CM	
	RE	1	0	PP5	DPP50	1	CM	
	C	1	0	PP5	DPP41	1	CM	
2G 0-180	P	0	2	PP7	DPP8	3	P2	
				PP7	DPP19	3	P2	
		1	0	PP7	DPP7	5	P2	
				PP7	DPP8	3	P2	
				PP7	DPP19	3	P2	
	RD							
	R	0	2	PP7	DPP15	3	P2	
				PP7	DPP16	2	P2	
				PP7	DPP20	2	P2	
				PP7	DPP41	1	P2	
		1	0	PP7	DPP13	3	P2	
				PP7	DPP20	2	P2	
	RC							
	RE	1	0	PP7	DPP50	1	P2	
	C							
3G 0-120-240	P							
	RD							
	R							
	RC							
	RE	0	4	PP21	DPP28	2	P3	
				PP21	DPP49	1	P3	
		1	2	PP21	DPP28	2	P3	
				PP21	DPP49	1	P3	
		2	0	PP21	DPP21	3	P3	
				PP21	DPP25	2	P3	
	C							
4G 0-90-180-270	P	3	0	PP30	DPP30	3	P4	
	RD	1	4	PP30	DPP38	2	P4	
				PP30	DPP41	1	P4	
		2	2	PP30	DPP35	2	P4	
				PP30	DPP38	2	P4	
				PP30	DPP41	1	P4	
	R							
	RC	3	0	PP30	DPP41	1	P4	
	RE							
	C	1	4	PP30	DPP39	2	P4	
				PP30	DPP41	1	P4	
		2	2	PP30	DPP38	2	P4	
				PP30	DPP39	2	P4	
		3	0	PP30	DPP30	3	P4	
				PP30	DPP35	2	P4	

4GR 0-180 R0-R180	P	1	4	PP17	DPP38	2	CMM	
		2	2	PP17	DPP15	3	CMM	
				PP17	DPP16	2	CMM	
				PP17	DPP17	4	CMM	
				PP17	DPP37	3	CMM	
	RD	2	2	PP11	DPP41	1	CMM	
	R	0	6	PP11	DPP15	3	PMG	
				PP11	DPP16	2	PMG	
				PP11	DPP41	1	PMG	
		1	0	PP10	DPP51	1	PGG	
		1	4	PP9	DPP16	2	PGG	C
				PP11	DPP15	3	PMG	D
				PP11	DPP16	2	PMG	C
				PP14	DPP14	4	PMM	
				PP14	DPP15	3	PMM	D
				PP14	DPP39	2	PMM	
				PP14	DPP41	1	PMM	
		2	2	PP9	DPP13	3	PGG	
				PP9	DPP19	3	PGG	E
				PP9	DPP20	2	PGG	
				PP9	DPP50	1	PGG	F
				PP9	DPP51	1	PGG	
				PP11	DPP11	4	PMG	
				PP11	DPP19	3	PMG	E
				PP11	DPP50	1	PMG	F
	RC	3	0	PP17	DPP15	3	CMM	
				PP17	DPP16	2	CMM	
				PP17	DPP17	4	CMM	
				PP17	DPP37	3	CMM	
				PP17	DPP41	1	CMM	
	RE							
	C	1	4	PP9	DPP41	1	PGG	G
				PP11	DPP41	1	PMG	G
				PP17	DPP38	2	CMM	
6GR 0-120-240 R0-R120-R240	P							
	RD							
	R							
	RC							
	RE	3	4	PP23	DPP48a	2	P31M	
				PP23	DPP48b	2	P31M	
				PP27	DPP27	3	P3M1	
				PP27	DPP47	2	P3M1	
				PP27	DPP50	1	P3M1	
		4	2	PP23	DPP48a	2	P31M	
				PP23	DPP48b	2	P31M	
		5	0	PP23	DPP23	3	P31M	
	C							
6G 0-60-120 180-240-300	P							
	RD							
	R							
	RC							
	RE	3	2	PP42	DPP48a	2	P6	
		3	4	PP42	DPP47	2	P6	
				PP42	DPP48a	2	P6	
				PP42	DPP48b	2	P6	
				PP42	DPP50	1	P6	
		4	2	PP42	DPP48b	2	P6	
		5	0	PP42	DPP42	3	P6	
	C							
8RG 0-90-180-240 R0-R90-R180-R240	P	5	4	PP37	DPP37	3	P4M	
	RD	3	8	PP33	DPP38	2	P4G	
				PP33	DPP39	2	P4G	
				PP33	DPP41	1	P4G	
		6	2	PP33	DPP33	3	P4G	
	R	5	4	PP37	DPP37	3	P4M	
	RC							
	RE							
	C	5	4	PP33	DPP38	2	P4G	
				PP33	DPP41	1	P4G	
		6	2	PP33	DPP39	2	P4G	
		7	0	PP33	DPP33	3	P4G	
12RG 0-60-120-180-240-300 R0-R60-R120 R180-R240-R300	P							
	RD							
	R							
	RC							
	RE	9	4	PP46	DPP46	3	P6M	
	C							

c2	1	P	0	0	PP8	DPP8	3	P2	
		RD	0	0	PP8	DPP20	2	P2	
		R	0	0	PP8	DPP16	2	P2	
		RC							
		RE	0	0	PP8	DPP51	1	P2	
		C	0	0	PP8	DPP41	1	P2	
	2R 0-R0	P	0	2	PP18	DPP16	2	CMM	
					PP18	DPP41	1	CMM	
		RD							
		R	0	2	PP12	DPP16	2	PMG	
					PP12	DPP41	1	PMG	
			1	0	PP10	DPP20	2	PGG	
		RC	1	0	PP18	DPP16	2	CMM	
		RE							
		C	1	0	PP10	DPP41	1	PGG	H
					PP18	DPP41	1	CMM	H
	2G 0-90	P							
		RD	1	0	PP31	DPP41	1	P4	
		R							
		RC							
		RE							
		C	1	0	PP31	DPP41	1	P4	
	3G 0-120-240	P							
		RD							
		R							
		RC							
		RE	0	4	PP43	DPP49	1	P6	
			1	2	PP43	DPP49	1	P6	
		C							

c3	1	P						
		RD						
		R						
		RC						
		RE	0	0	PP22	DPP51	1	P3
		C						
	2R 0-R0	P						
		RD						
		R						
		RC						
		RE	1	0	PP24	DPP50	1	P31M
		C						
	2G 0-180	P						
		RD						
		R						
		RC						
		RE	1	0	PP44	DPP50	1	P6
		C						

c4	1	P						
		RD						
		R						
		RC						
		RE						
		C	0	0	PP32	DPP41	1	P4
	2R 0-R0	P						
		RD	0	2	PP34	DPP41	1	P4G
		R						
		RC						
		RE						
		C	1	0	PP34	DPP41	1	P4G

c6	1	P						
		RD						
		R						
		RC						
		RE	0	0	PP45	DPP51	1	P6
		C						

Table 2.

d1	1	P							
		RD	0	0	PP6	DPP20	2	CM	
		R	0	0	PP4	DPP16	2	PM	
		RC							
		RE	0	0	PP6	DPP20	2	CM	
					PP6	DPP51	1	CM	
		C	0	0	PP4	DPP41	1	PM	I
					PP6	DPP41	1	CM	I
	2R 0-R0	P	0	2	PP19	DPP16	2	CMM	
					PP19	DPP19	3	CMM	
					PP19	DPP41	1	CMM	
					PP19	DPP50	1	CMM	
		RD	1	0	PP19	DPP19	3	CMM	
		R	0	2	PP13	DPP16	2	PMG	J
					PP13	DPP41	1	PMG	K
					PP15	DPP15	3	PMM	
					PP15	DPP16	2	PMM	J
					PP15	DPP41	1	PMM	K
			1	0	PP13	DPP13	3	PMG	
						DPP20	2	PMG	
						DPP51	1	PMG	
		RC	1	0	PP19	DPP16	2	CMM	
						DPP19	3	CMM	
		RE	1	0	PP19	DPP50	1	CMM	
		C	1	0	PP19	DPP41	1	CMM	
	3G=3R 0-120-240	P RD R RC							
		RE	0	4	PP28	DPP28	2	P3M1	
					PP28	DPP49	1	P3M1	
			1	2	PP28	DPP28	2	P3M1	
					PP28	DPP49	1	P3M1	
			2	0	PP25	DPP25	2	P31M	
					PP25	DPP51	1	P31M	
		C							
	4G=4R 0-90-180-270	P							
		RD	1	4	PP35	DPP41	1	P4G	
					PP38	DPP38	2	P4M	
			2	2	PP38	DPP38	2	P4M	
			3	0	PP35	DPP35	2	P4G	
		R RC RE							
		C	1	4	PP35	DPP41	1	P4G	
					PP39	DPP39	2	P4M	
			3	0	PP35	DPP35	2	P4G	
			5	4	PP38	DPP38	2	P4M	
	6G=6R 0-60-120-180-240-300	P RD R RC							
		RE	3	4	PP47	DPP47	2	P6M	
					PP47	DPP50	1	P6M	
					PP48	DPP48a	2	P6M	
					PP48	DPP48b	2	P6M	
			4	2	PP48	DPP48b	2	P6M	
		C							
d2	1	P							
		RD	0	0	PP20	DPP20	2	CMM	
					PP20	DPP51	1	CMM	
		R	0	0	PP16	DPP16	2	PMM	
		RC	0	0	PP20	DPP20	2	CMM	
		RE	0	0	PP20	DPP51	1	CMM	
		C	0	0	PP16	DPP41	1	PMM	L
					PP20	DPP41	1	CMM	L
	2G 0-90	P							
		RD	0	2	PP36	DPP41	1	P4G	
		RD RC RE							
		C	0	2	PP40	DPP41	1	P4M	
			1	0	PP36	DPP41	1	P4G	M
					PP40	DPP41	1	P4M	M
	3G 0-120-240	P RD RD RC							
		RE	0	4	PP49	DPP49	1	P6M	
			1	2	PP49	DPP49	1	P6M	
		C							
d3	1	P RD R RC							
		RE	0	0	PP26	DPP51	1	P31M	N
					PP29	DPP51	1	P3M1	N
		C							
	2G 0-180	P RD R RC							
		RE	1	0	PP50	DPP50	1	P6M	
		C							
d4	1	P RD R RC RE							
		C	0	0	PP41	DPP41	1	P4M	
d6	1	P RD R RC							
		RE	0	0	PP51	DPP51	1	P6M	
		C							

Table 3.

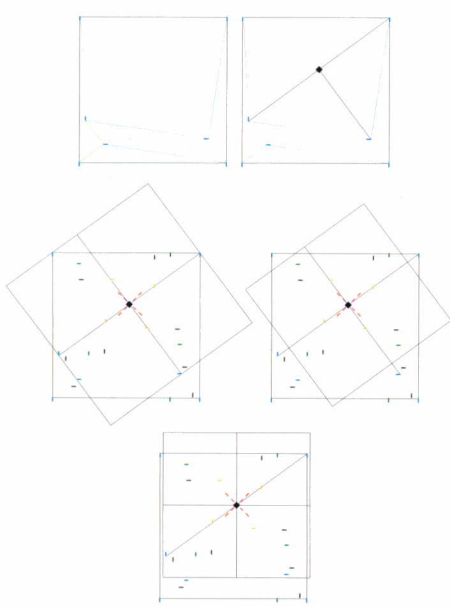


Figure 7.

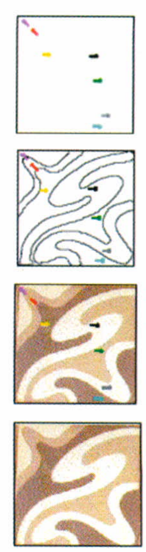


Figure 8.

Case I: d1 / 1 / C / I0, L0 / DPP41 / 1 parameter / possible groups PM and CM.

- PM.- There is a reflection going through the midpoints of opposite parallel sides of the fundamental parallelogram.
- CM.- There are two sliding reflections going through the midpoints of contiguous sides of the fundamental parallelogram.

In the example given, the fundamental parallelogram is defined by a shape with a C1 point symmetry group, which is repeated inside the parallelogram according to three different orientations corresponding to rotations of 90°, 180° and 270° in respect of the one determining the parallelogram. The parallelogram is specifically a square. Considering these data and entering them in the table, a plane symmetry group is found for analysed design P4. To verify whether this is really the existing plane symmetry group, it needs to be confirmed that on adding the remaining different shapes of the design, the isometries defining the group found are maintained. Thus, this plane symmetry group requires a fourth order rotation (0°, 90°, 180° and 270°) at the exact point marked in the parallelogram, shown in Figure 7.

To find the minimum region (the one contained in the fundamental parallelogram, which by different isometries is capable of generating the fundamental parallelogram), it suffices to consider the generator of each of the 17 plane symmetry groups set by Schattschneider (1978) and by Abas and Salman (1992). In the example at issue, where the plane symmetry group is P4, the minimum region will be a square, whose side will have a length equal to half the length of the side of the fundamental parallelogram (Figure7).

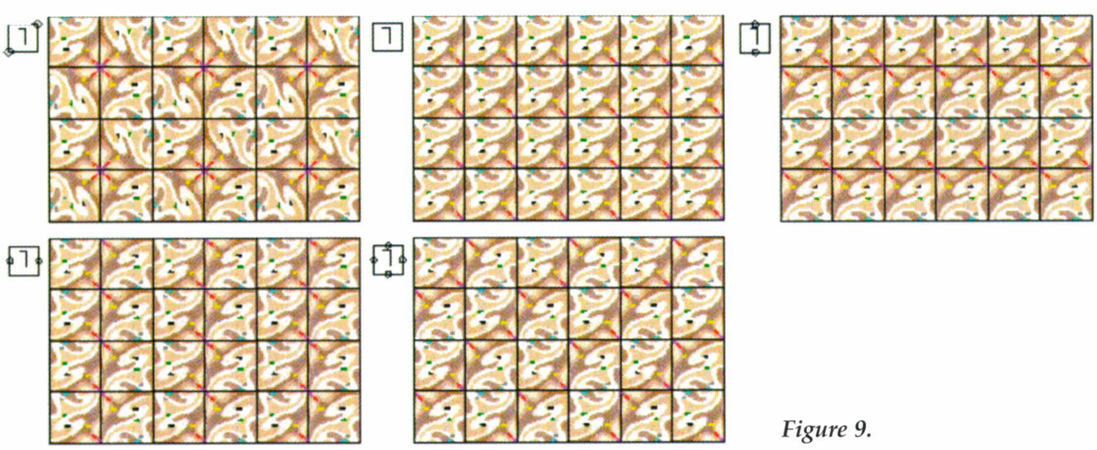


Figure 9.

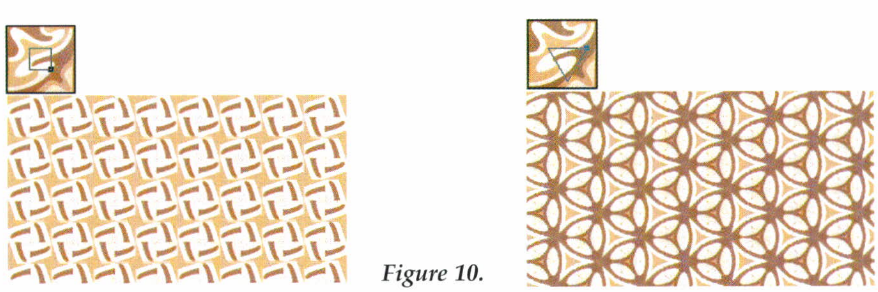


Figure 10.

If the points contained in the minimum region are replaced by the shapes associated with each point, the image of the tile is found, which produced the original design (Figure 8).

Cataloguing the minimum region is an automatic verification process of the isometries (just rotations and reflections) existing in the region. In the case at point, the only existing isometry in the minimum region found is a 360° turn, so that this will correspond to a C1 symmetry group.

EXITING the module. There are three types of exit documents: pattern, fundamental parallelogram and minimum region, and there may or may not be a graphic indication of the isometries that each generates.

CONNECTION with other modules. Previous module: Detection. Following modules: database and / or Generation.

4.3. MODULE FOR GENERATING NEW PATTERNS

This module is designed to produce the greatest possible number of compositional solutions that may be obtained from a minimum region extracted from the original pattern. Generating these new patterns is done by applying elementary transformations to the minimum region to create new fundamental parallelograms, and thus subsequently, by successive repetition of this different fundamental parallelogram, generate a new pattern.

ENTERING the module. The entry datum will be the minimum region found in the analysis module.

PROCESS in the module. Two different generation modes are used to generate new patterns, based on the application of isometries in previously determined points in the minimum region, derived from the isohedral marked tilings of Grünbaum and Shephard (1987), and based on the consideration of the types of basic reticulations associated with each of the 17 plane symmetry groups, derived from the group generators set by Schattschneider (1978) and Abas and Salman (1992).

In the first case, each minimum region can be the object of certain transformations at concrete points of its perimeter, and generate a limited number of patterns in which the minimum region symmetries are pattern symmetries. A study of this case can be found in Gomis and Valor (1996), with an amplification in Valor and Gomis (1996). Thus, in the example put forward, starting from the minimum region with symmetry group C1, the patterns that can be generated are those presented in Figure 9, in each case indicating the applied isometries.

In the second case, taking any part of the fundamental parallelogram or minimum region, a new pattern is generated. The advantage in this case lies in the infinite number of patterns that can be generated, but it also entails the disadvantage of not being able to wholly respect the elementary forms, as the selection of any given part necessarily has an external figure made up of straight lines that usually cut the elementary shapes. Thus, as an example, the designs presented in Figure 10 could be generated from the proposed design.

EXITING the module. There are two types of exit documents: the different patterns that can be generated and a given pattern.

CONNECTION with other modules. Previous and following module: Analysis

4.4. DATABASE

The database serves to store all the data on the catalogued images. All the information that accompanies the saved patterns is determined in two different ways: the information that can be obtained automatically (format, size, colours, symmetry group, etc.), and the information that needs to be entered by the user (location, manufacturer, components, etc.).

The database is equipped to save new images and their associated information, retrieve the information on the saved images, edit the information on the saved images, eliminate records and perform searches according to a series of criteria set by the user.

To structure the database, a distinction is made between sample and item. By sample is meant the whole image representing the whole design, while by item is meant the independent units making up the sample. The data structure used is as follows:

DATA ON THE SAMPLE

1. Design sample: containing the pattern, fundamental parallelogram, and minimum region.
2. Location of the sample: indicating the complete address of the location from which the sample was extracted, as well as type of use (floor, wall or roof).
3. Manufacturer: company name and address.
4. Dates of note: date of appearance of the design, as well as date on which the practical application to which the sample refers was produced.
5. Obtainment of the images: means used to obtain the image (traditional photography with subsequent scanning, digital photography, scanning of book, pamphlet or any other type of document), and in every case the date of image obtainment.
6. Different items making up the sample: indication of the number of different items, whether by format (in reference to perimeter shape), or by total shape (differences in shape, size, colour and/or texture).

7. Sample plane symmetry group.
8. Predominant colour: determining the palette of the sample (original sample colours).

DATA ON THE ITEM

1. Type of ceramic product: the Brongniart (1844) classification can be used: terra cotta, lustrous product, varnished product, glazed product (common earthenware), fine earthenware, stoneware, hard porcelain, natural soft porcelain, and artificial soft porcelain.
2. Perimeter shape or format: two large groups are considered: convex polygons and concave polygons (stars). Each group is then sub-classified according to type of format side: straight sides, curved sides or mixed sides.
3. Size or Dimension: three characteristics are to be determined: length of sides in cm, diameter of the circumference circumscribing the item in cm, and item thickness in mm.
4. Predominant colour: determining the palette of the item (original item colours) and transformed palette (transformation of the item palette to a general pre-established palette).
5. Surface finish: distinguishing two types: tactile (even - smooth; rough - uneven; profiled - moulded, stamped, recessed, engraved, printed, incrusted) and visual (matt, glossy).
6. Shape contained: this refers to the motif shown on the item. To define the shape contained it is necessary to divide the information into the following sections:

   a) Formal configuration: distinguishing between: simple shape (a single shape), multiple shape (composition with identical shapes), composite shape (composition with different shapes).
   b) Type of figure: with regard to the way in which the shape is expressed or represented, hand-drawn (created freehand), organic (soft, free curves, in which signs of hand drawing are minimised), geometric (mathematically constructed by mechanical means), rectilinear (limited by straight, mathematically unrelated lines), irregular (limited by curved lines and straight lines) or accidental.
   c) Point symmetry group.
   d) Representation: distinguishing between abstract and figurative. Abstract shapes are difficult to sub-classify, as it is impossible to determine something in words, which by its very condition does not suggest anything, so that the sub-classification depends on the type of figure set out above. In contrast, figurative shapes can be sub-classified in terms of: natural or artificial, it being possible in each case to create more concrete sub-sections, as the items are entered. Thus for example, natural figurative shapes can be animals, plants, algae or mushrooms.

This original database structure (featuring the possibility of being able to reduce or amplify, suppress or add data), with an extensive definition of the specific characteristics of each sample and item, enables making abundant consultations. The purpose of the consultations will vary according to the desired results. It is thus possible for example to find out how many different designs a manufacturer offers, which is the most widely used shape or colour, ascertain what is the most frequently used regular arrangement, or which types of formats are most widespread.

4.5. IMAGE PROCESSING MODULE

The fact of wishing to provide the application with the possibility of editing existing designs as well as of creating new ones made it necessary to include typical image processing functions.

ENTERING the module. The entry datum will always be a file containing a design image. The origin of this file can be internal or external to the database, or even newly created.

PROCESS in the module. In this module of the application, different tools are distinguished that allowing creating new images or modifying existing ones. The basic tools involved are as follows: drawing tools and attributes, visualisation, operations with files, editing and modifying tools, colour and vectoring tools.

EXITING the module. The exit datum will be a file containing an image.

CONNECTIONS with other modules. Previous module: Database consultation. Following module: Detection.

4.6. SIMULATION MODULE

This module is designed to produce a virtual image of the selected pattern in a pre-set environment.

ENTERING the module. The entry datum is always a file containing a design image. The origin may be internal or external to the database.

PROCESS in the module. There are two possible processes in this simulation module. One is based on a bit map image and the other uses a 3-D vectorial image as a base for the simulation. In both cases, the images to which the selected design simulation is applied are prepared in order to determine the areas in the bit map files, and the surfaces in the vectorial files, on which the design is to be entered, so as to produce a realistic image of the adopted solution.

EXITING the module. The exit datum will be a file with an image in which the selected design is visualised, integrated in a given environment.

CONNECTIONS with other modules. Previous module: Database consultation.

5.- CONCLUSIONS

The great supply of products has led to a continuous product evolution that reduces the product life cycle and entails a logical striving to develop new products or diversify existing ones. This also requires fast, efficient product development. Accepting these premises will provide companies with singular characteristics and yield competitive advantages.

The development of the project will provide a computer tool that saves design time and diversifies the products designed for the ceramic sector. The project also includes the possibility of cataloguing not just the newly created designs but also the existing designs, which permits structuring all the existing information, and readily obtaining the necessary information in an acceptable time. In this sense, the time needed for creating new designs and the obtainment of variants from other already existing ones is reduced, thus shortening the product development cycle.

The subsequent use of the designs generated on virtual scenarios will provide a more accurate view of the end product to be made, allowing a multitude of prototypes to be developed, and only actually making the most feasible ones, with the ensuing savings in making samples and physical prototypes. On the other hand, the use of virtual design techniques can be used not just by designers for developing new products, but also by the agents in the last link of the merchandising chain, enabling them to present the customer with a more accurate view of the effect of a given product.

6. REFERENCES

[1] ABAS, S.J.; SALMAN, A. *Geometric and Group-theoretic Methods for computer Graphic Studies of Islamic Symmetric Patterns.* Computer Graphics Forum (1992, Vol. 11, n° 1, 43-53).

[2] Alt, H.; Mehlhorn, K.; Wagener, H.; Welzi, E. *Congruence, Similarity, and Symmetries of Geometric Objects.* Discrete Comput Geometry (1988, Vol. 3, 237-256).

[3] ATALLAH, J. M. *On Symmetry Detection.* IEEE Transactions On Computers (1985, Vol. C-34, N° 7, 663-666).

[4] DINGGANG, S. IP; H.S.H. CHEUNG; K.T.K. KHWANG, T. E. *Symmetry Detection by Generalized Complex (GC) Moments: A Close-Form Solution.* IEEE Transactions On Pattern Analysis And Machine Intelligence (1999, Vol. 21, 5, 466- 476).

[5] EADES, P. *Symmetry Finding Algorithms.* Toussaint, GT (ed) Computational Morphology (1988, 41-51).

[6] GOMIS, J.M. VALOR, M. *Aplicación de la Teoría de Grupos de Simetría a la Catalogación de Revestimientos Cerámicos de Formato Cuadrado. IV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico.* QUALICER 1996.

[7] GRÜNBAUM, B. SHEPHARD, G.C. *Tilings and Patterns.* W.H. Freeman and Company, New York, 1987.

[8] HIGHNAM, P.T. *Optimal algorithms for finding the symmetries of a planar point set.* First International Conf. On Computer Vision, London (june 1987, 433-438).

[9] KAUPPINEN, H.; SEPPÄNEN, T.; PIETIKÄINEN, M. *An Experimental Comparison of Autoregressive and Fourier-Based Descriptors in 2D Shape Classification.* IEEE Transactions On Pattern Analysis And Machine Intelligence (1995, Vol. 17, n° 2, 201-207).

[10] KIRYATI, N.; GOFMAN, Y. *Detecting Symmetry in Grey Level Images: The Global Optimization Approach.* International Journal Of Computer Vison (1998, Vol. 29, 1, 29-45).

[11] LEOU, J-J.; TSAI, W-H. *Automatic rotational symmetry determination for shape analysis.* Pattern Recognition (1987, Vol. 20, n° 6, 571-582).

[12] LIN, J-C.; CHOU, S-L.;TSAI, W-H. *Detection of rotationally symmetric shape orientations by fold-invariant shape-specific points.* Pattern Recognition (1992, Vol. 25, N° 5, 473-482).

[13] LLADOS, J.; HORST BUNKE, H.; MARTI, E. *Finding rotational symmetries by cyclic string matching.* Pattern Recognition Letters (1997, Vol. 18, 1435-1442).

[14] MAROLA, G. *On the detection of the axes of symmetry os symmetric and almost symmetric planar images.* IEEE Transactions On Pattern Analysis And Machine Intelligence (1989, Vol. 11, n° 1, 104-108).

[15] SCHATTSCHNEIDE, D. *The Plane Symmetry Groups: Their Recognition and Notation.* The American Mathematical Monthly (1978, Vol. 85, 439-450).

[16] STEIN, F. *Perceptual Grouping for Generic Recognition. International Journal Of Computer Vision* (1996, Vol. 20, 59-80).

[17] SUN, C.; SI, D. *Fast Reflectional Symmetry Detection Using Orientation Histograms.* Real-Time Imaging (1999, Vol. 5, 63-74).

[18] TSAI, W-H.; CHOU, S-L. *Detection of Generalized Principal Axes in Rotationally Symmetric Shapes.* Pattern Recognition (1991, Vol. 24, n° 2, 95-104).

[19] VALOR, M.; GOMIS, J.M. *Paralelogramos Fundamentales En La Cubrición Del Plano Mediante Formatos Rectangulares.* VIII Congreso Internacional de Ingeniería Gráfica. Publicaciones de la Universidad de Jaen (1996, Vol. 1, 145-160)

[20] WOLTER, J. D.; WOO, T. C.; VOLZ, R. A. *Optimal algorithms for symmetry detection in two and three dimensions.* The Visual Computer (1958, Vol. 1, 37-48).

[21] ZABRODSKY, H.; PELEG, S.; AVNIR, D. *Symmetry as a Continuous Feature.* IEEE Transactions On Pattern Analysis And Machine Intelligence (1995, Vol. 17, n° 12, 1154-1166).

[22] ZAHN, C.T. ROSKIES, R.Z. *Fourier descriptors for plane closed curves.* IEEE Trans. Computers (1972, Vol. 21, n° 3, 269-281).