# Phase Space Portraits of the Nuestra Señora delos Dolores of Baclayon Church in Bohol

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## ABSTRACT

This paper outlines the concept, media and processes used in the application of the mathematical concept of Recurrence Plots to determine the coloring of patterns and the design of planar symmetry for three phase space portraits of the Spanish colonial sculpture, the *Nuestra Señora de los Dolores* of Baclayon Church in Bohol. Baclayon Church is a Heritage Site in the Philippines, established by the Jesuits in 1595 and the present coralstone edifice built in 1727. The *Dolorosa* was acquired in 1861.

Three phase space portraits were produced in this study, using digital imaging processes with analog studio techniques, in particular, engraving and reverse gilding on glass. There are a few rare examples of reverse glass painting and gilding in the Philippines dating to the Spanish colonial period. One can be found at the Baclayon Church in Bohol, and it is this rare piece that motivated the research on and exploration with reverse work on glass for the final structure of the phase space portraits.

**Keywords:** digital art, religious art, recurrence plot, colonial sculpture, santo, symmetry, pattern, glass, gilding

## 1. INTRODUCTION

My long-standing interest in Spanish colonial *santos* (sculpted images of saints) and other forms of religious art culminated in a digitization initiative and research in traditional *santo*-making which I started near the end of 1998 and completed in 2000. The research was conducted through a grant from the Program for Cultural Cooperation by the Ministry of Education and Culture of Spain. During the course of the research I stayed in Baclayon Church, in a room just a door away from the museum. Every morning, I got up to work, excited to see one of my favorite *santos* in the museum, the *Dolorosa* (see Figure 1). When I finished my work in Baclayon, all that I could bring home with me, of course, were digital and film photographs and textual descriptions and measurements of the *santos* in that church. Since then, I have embarked on a quest, a journey, to replicate, approximate, the image of the *Dolorosa*. I tried a variety of methods - painting, sculpture, photography. But all of my efforts were only approximations; although my paintings, sculptures and photographs very well captured the likeness and image of my subject, it was not a conceptually satisfying representation of the spiritual and the divine that I experienced in the *Dolorosa.*

In this journey in *santo*-making, I found that my interest in the use of computers in art and scientific visualization would serve as inspiration, motivation and tool. I started using computers in 1992 and initial interests were in word processing, desktop publishing and digital image manipulation and printmaking. In the mid-90's I moved on to multimedia and web design. Later, my interests directed from the creative to the technical and scientific applications: bulletin board systems, artificial intelligence, iterated function systems, 3D image processing for MRI data, and fractals. So just when I was completing my *santo* research, I was already involved in visual programming and information visualization. I felt that science and mathematics became more accessible because of computers, and that even the most difficult concepts in the overlapping of mathematics and physics became understandable. This is because computers allowed a visualization of them. In fact, one of the most popular and fascinating visualizations is the specialist field of fractals, and it was this field of interest that led me to look into the Theories of Chaos and Complexity.

The Complexity sciences attempt to explain the motion of celestial bodies, the processes in nature, the irregular shapes of clouds, coastlines, flowers and trees, and the articulation of human behavior. So it was precisely in the Chaos and Complexity Sciences that I would find the tools, the grammar and visualization that I needed to represent concepts of the spiritual and the divine.

*Figure 1. The Dolorsa of Baclayon Church.*

## 2. THE IMAGE OF THE DIVINE

At this point, one might ask, what is my idea, my concept, my notion of the spiritual and the divine? The human desire to de-

fine and express such concepts have a long and ancient history, but what is it that intimately, genuinely means the spiritual and the divine to me?

As I go back to my first encounter with the *Dolorosa*, I find many answers. But the most compelling is the presence of a magical identity between the *santo* and the saint - that intellectual principle of sympathy that allows objects and their entities in the world and beyond to act upon each other at a distance.

In Christian art, it is the doctrine of the prototype, the doctrines that gave icons their magical powers and turned them into doorways into heaven. In Islamic art, this is the principle of emanation, that there is a movement in the hierarchy from descent of light, to expansion into creation, and to a return to the source, a principle reflected in Islamic patterns and calligraphy. For the ancient Greeks, it is the rhythmic relations of all things governed by measure and expressed in mathematical proportions such that the study of mathematics was deemed a source of divine wisdom.

In all this, I saw the underlying principle of oneness, the relationship of the part to the whole, the interconnectedness, inseparability and union that provides us with a continuous reminder of our relationship to the whole, a blueprint for the mind to the sacred foundation of all things created. At that instance, I knew exactly what to look for.

## 3. FROM *SANTO* TO SIGNAL

### 3.1 Visual Qualitative Analysis

A Recurrence Plot is a visualization tool for analyzing experimental data. It is a relatively new technique first discussed in a journal of Europhysics Letters in 1987 by Eckmann, Kamphorst and Ruelle. Recurrence Plots *(see Figure 2)* is the application of the basic idea that from a single observable behavior, it is possible to recreate a topologically equivalent picture of the original multidimensional system, because the effect of all the other unobserved variables is already reflected in the single observable behavior. This topologically equivalent picture is the phase

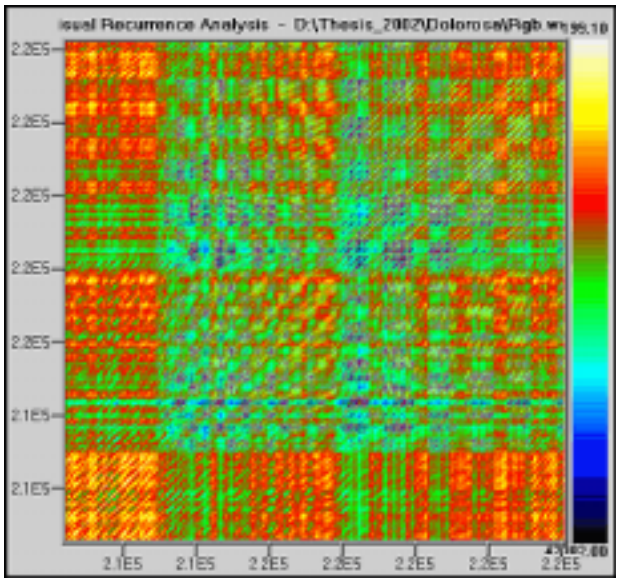


*Figure 2. Recurrence Plot of Dolorosa RGB Signal.*

space, the mathematical abstract space, which represents a full description of the system. Easily, this reminded me of the principle of oneness, the relationship of parts to the whole. When I learned about Recurrence Plots and the remarkable concepts behind them, I felt as if a connection had been made.

There are several other visualization tools developed in the various specialized fields in the Chaos and Complexity Sciences, but I selected the Recurrence Plot because it is, unlike the others, mostly a qualitative visualization tool. In fact, mathematicians themselves admit that the pictures generated by Recurrence Plots carry meaningful information about the underlying signal, but because it is mostly a qualitative tool, the precise meaning of the patterns is unknown. But as far as the artist is concerned, this is the tool that will satisfy the symbolic application of the Complexity sciences in representing concepts of the spiritual and the divine. If I were to use a quote to describe the Recurrence Plot, it would be from the book of St. Mark, chapter 6 verse 56:

> "And they besought Him that they might touch, if it were, but the border of His garment; and as many as touched Him were made whole."

The Recurrence Plot software I used in this thesis is Visual Recurrence Analysis or VRA. VRA was developed by Eugene Kononov, a Russian Physicist working and living in the US. In an email correspondece, Eugene confirmed how mathematicians and physicist have been advancing towards the other side in the pendulum swing that brings art and science together: "One of the revelations that I got from researching and implementing VRA is that music, paintings, and physical processes as we observe them are just different representations of certain patterns in nature, and can be transformed into one another."

### 3.2 Digitization

A critical step in producing the works in this study is digitization. Digitization turns analog data (here, the raw image of the *santo*) into a digital code or a numerical representation (signal). Digital artists call the result, a "new media object." Whereas as digital data is discrete or occurring in distinct units, analog data is largely continuous, that is, the axis or dimension that is measured has no apparent indivisible unit from which it is composed. [Kerlow and Rosebush 1986].

Overall, the numerical representation of data means that a new media object can be described formally, as, for instance, in a mathematical function; and it is subject to algorithmic manipulation, such as in the application of a filter, the distortion of an image, the inversion of a sound, or the selection of specified color pixels. New media objects also have a modular structure analogous to fractals that remains the same on different scales.

In this research, before Recurrence Plots were made, the image was split into three channels - Red, Green and Blue, the RGB color model - represented by vectors (numerical representation). Each channel is an independent modular structure that is stored separately from the larger combined RGB image.

As digitization turns media into computer data that displays a structural organization human and sensible, it also takes on yet

another organizational structure following the established conventions of the computer's organization of data. The *santo* digital image, on the level of representation with content, shape, color, motif, pertains to the human aspect of culture, sensible to human visual perception and negotiation for meaning. But as a digital image, it is a computer data consisting of patterns of dots called pixels or picture elements, a machine-readable header, and equivalent numbers representing the RGB color value of its pixels. Understandably, it is sensible with other computer files, not on the level of meaning or content or form, but on the computer's own language.

> In new media lingo, to "transcode" something is to translate it into another format. The computerization of culture gradually accomplishes similar transcoding in relation to all cultural categories and concepts. That is, cultural categories and concepts are substituted, on the level of meaning and/or the language, by new ones which derive from computer's ontology, epistemology and pragmatics. New media thus acts as a forerunner of this more general process of cultural re-conceptualization. [Manovich 2001]

Understandably, the conversion of the *santo* into a digital image involved the process of transcoding, with the graphics converted into a numerical representation and with each of the pixels assigned a numerical value to define its color. The process splits the image into three channels - Red, Green and Blue - the RGB color model, one of several established models for describing and reproducing color. Practically the entire visible spectrum may be represented by mixing red, green, and blue colored light in various proportions and intensities and there are numeric values for each color component in each channel: (0 is black, and 255 is the pure color (white). As discrete vectors, each channel (signal) in the image can be plotted into a graph, displayed as space-delimited .PRN data, or assigned to specific pixels of color.

In contrast to the sculptural image of the *santo*, its signal counterpart is mutable, it can be modified into various dimensions and can exist in numerous states and forms. The signal is a one-dimensional expression of the *santo* brought to higher dimensional space through the mathematical concept of Recurrence Plots.

I selected a digital photo of the *Dolorosa* that showed this *santo* as viewed by a devotee looking up, then I derived three signals from this image, each representing the 3 additive colors in the RGB color system, the color system that reproduces colors nearest to how we perceive them. Recurrence Plots were then produced from these signals. I used digital color maps to determine the color scheme of the Recurrence Plots, and used a wide format Epson printer to print them on backlit film media. The film prints were then stretched between two acrylic sheets. But my phase space portraits do not end here.

## 3.3 Symmetry and Pattern Recognition

If carved images of saints were dressed and bedecked with *rostrillos* (a face framing halo), nimbuses, crowns and the like, I felt I could do the same thing with my phase space portraits. As I was making the Recurrence Plots and observing the patterns in the Recurrence Plots, what I saw was symmetric chaos. I knew that I could use the patterns to produce the symmetry designs that will crown my portraits. The relationship between pattern and symmetry is clear: pattern is the arrangement of parts that consists of an organized system based upon repetition; and the analysis of symmetry allows for understanding the organization of pattern.

Pattern and symmetry's universality and extensiveness has given them the status of philosophic category expressing the fundamental laws of organization in nature. Through geometry, this has been extensively explored in Islamic art, a powerful form of sacred representation. Keith Critchlow states in the book "Islamic Patterns": "Geometry is a language ideally suited to the expression of the fundamental principle of experiencing of the parts and whole. It is in symmetry - the principle of repetition by reflection - that this can be shown most clearly."

The basic symmetry analysis and construction method I used was to decompose the Recurrence Plot patterns by symmetry groups to obtain a region, and use that region to infer geometry for the remaining regions. In describing the symmetry groups I designed in the three phase space portraits, I used crystallographic notations: p1 for a type of symmetry covering the plane, and D4, D6 and D12 symmetry group of rosettes for "Signal No. 1"; the synmmetry group of Frieze $F2^2$ for "Signal No. 2"; and pm or p1m symmetry covering the place for "Signal No. 3." I produced the designs, rendered them on glass through engraving, etching and gilding, mounted the glass on the printed Recurrence Plots and enclosed them in stainless steel frames. I used backlighting to play up the effervescence, luminosity and reflectivity of the materials used in the work.

The finished works, as I envisioned them to be, are the products of several other processes. Each phase space portrait consists of two layers of images, one on top of the other. On the lower layer, the Recurrence Plot was printed on film and mounted between acrylic plastic sheets, while on the upper layer, the symmetry design derived from the Recurrence Plot was rendered on glass through engraving and gilding. Light is a very important factor in the final composition because back lighting is needed to bring out the colors of the Recurrence Plot in the lower layer while front lighting is needed to reflect the engraved and gilded designs on the upper layer. The general effect of the pieces expresses my apprehension of religious images as reflections of spirituality, divinity and magical identity.

"Signal No. 1 (Blue)" is the *Dolorosa* presented to remind me of the color of her *encarne* (skin tones painted in the traditional way), her dark mourning gown, the silver beadwork of her dress, her silver *rostrillo*, and the presence of the crucifixion, completing the image of the mother lamenting the death of her son. "Signal No. 2 (RGB)" is the *Dolorosa* in full ornamentation, allowing me to fully explore techniques in engraving, reverse glass gilding and etching. "Signal No. 3 (Red)" is the *Dolorosa* crystallized in biomorphic form, with engraving and gilding techniques used to conceal seven areas in the pattern, therefore revealing seven areas that correspond to the seven sorrows of the *Dolorosa*.

The three works are installed at the 2nd floor of the Dept. of Electronics and Electrical Engineering (EEE) building in the University of the Philippines, Diliman campus in Quezon City (see Figure 3).

*Figure 3. Installation at the EEE.*

## 4. MEDIA AND PROCESS

In producing the first phase space portrait, "Signal No. 1 (Blue)", I was inspired by various art objects, particularly the *rostrillo* of the *Dolorosa*. I also planned to design this phase space portrait after the rose windows of Gothic cathedrals. The stained glass effect of the backlit film expresses my apprehension of the mysterious spiritual qualities of the *santo*. With this in mind, I selected the colors from the *encarnaciones* of the *Dolorosa*, namely, umber, crimson and flesh, for the Recurrence Plot. For the darkly tinted glass, I derived the color from the *Dolorosa's* mourning gown. The emanating rays on the glass in silver leaf recall again the *rostrillo* of the *santo* as well as the silver beadwork of her dress.

I applied various embedding and delay values to the *Dolorosa*'s blue vector Recurrence Plot until I realized a pattern, which looked like non-perpendicular translations of a p1 symmetry, the simplest plane symmetry. (In Crystallographic notation for symmetry groups, the letter *p* means primitive cell and 1 means no symmetry axis perpendicular to the "x-axis.) Points were selected on the pattern and traced to all the translations of the symmetry group to produce lattice points. Lattice points are not unique and on a single periodic tiling as in this case, different selections for departure points can result into different spatial locations for lattice points. The same is true with lines constructed to merge the lattice points.

The blue vector Recurrence Plot offered its own lattice of diagonal lines. However, I decided to ignore the apparent rhombic lattice type and locate other points. What resulted was a hexagonal lattice. Drawing lines across these lattice points can also produce a variety of divisions of the plane area.

Looking at the Recurrence Plot again, and this time following the rhombic lattice type of the pattern, I isolated a primitive cell which is that region in the periodic tiling that generates the entire pattern by translation. The primitive cell can be recognized as a continuous symmetry group of a circle, a rosette with maximal symmetry. Drawing a vertical and horizontal line across the cell results in the characteristic perpendicularity of a rosette with symmetry group $D_4$ (In crystallogaphic notation, D stands for dihedral symmetry group of rosettes. The number indicates the number of rotations perpendicular to the "x-axis" where "x-axis" is actually the left vertical edge of a cell.) Rosettes date back to the Paleolithic art and represent the oldest examples of the human aim to express regularity and symmetry. [Jablan 1995]. At this instance, aesthetic decisions were made based on the possibilities of following the non-perpendicular translations in a p1 symmetry to create a tiling or of using the symmetry group of rosettes suggested by the Recurrence Plot's primitive cell. I selected this particular rosette for the purpose of increasing visual and spatial contrast between the Recurrence Plot pattern and the symmetry and obtaining it by reducing it to a one-to-one mapping but still retaining the congruence by preserving the vertical and horizontal axes of symmetry. Small versions of the symmetry designs were printed on paper to help in the initial decisions on which areas the gilding, engraving and etching work on glass would be made.

I copied the design on the glass with a felt tip pen, applying necessary changes as the work progressed. I also copied the design based on the $D_6$ rosette on the reverse side of the glass. From the "downgraded" rosette symmetry group, it was possible to visually identify areas to be filled in with etching work which would will appear underneath the engraving. With the use of a Dremel tool with diamond point and carbide bits of various sizes, I started the engraving work following the lines drawn on the glass as well as the lines and patterns of the Recurrence Plot. The engraving and etching (carbide bit grinding) were done on 3/8" thick brown (bronze) glass. The Recurrence Plot can be seen underneath the glass. On the front of the glass I engraved the design with a diamond point, while on the reverse, I ground and etched the surface with a carbide bit.

To help determine the areas to be gilded, I took a digital photograph of the Recurrence Plot with the engraved and etched glass on top of it. I printed this digital photograph on paper to study which areas of the work will be gilded. I also printed the symmetrical design and drawings of the engraved and etched areas on paper to serve as guides. Once the areas to be gilded were determined, I prepared the glass for gilding.

I washed down the glass to scrub away debris from the etching and engraving work. For the gilding, I used a technique called water gilding. Water gilding involves the preparation of a water-based size or adhesive. The gold leaf I used is 23ct, which is standard, and the silver leaf is 12ct white gold (patent white gold leaf). The leaf came in books containing 25 sheets measuring approximately 3.25 square inches. Only loose leaf, and not transfer leaf, was used.

I prepared a water size consisting of glair (egg white) then I applied it on the area to be gilded. The leaf is to be applied on the wet area. Incidence of wrinkling was reduced by gently dabbing it with more size. To apply the leaf more easily, I cut it to appropriate size first, then gently rubbed down any tears, bumps, or wrinkles with a soft brush. The gild was left to dry before a second wash of size was applied. In some areas, after the gild was completely dry, I did more engraved designs.

Finally, I applied gold and silver leaf on both sides of the glass. The intention is to make the gilding in front appear floating above

*Figure 4. Application of silver leaf on the glass and the finished work.*

the engraved lines and the back gilding to shine through the etched areas that at the same time reflect the light illuminating the front part. The back lighting shines through the areas that are not gilded enhancing the glimmer of the gilded areas, but this light is not intense since it is diffused by the chalk white acrylic sheet and the backlit film print of the Recurrence Plot. To enrich the visual experience, I also applied gold and silver leaf on top of the etchings on the reverse side of the glass (Figure 4).

In the second phase space portrait of the *Dolorosa* entitled "Signal No. 2 (RGB)", I used the combined RGB vectors of the *santo*. The Recurrence Plot generated revealed a bounded pattern, that is, without a periodic tiling on the plane. This Recurrence Plot departs from the regular tiling of the *Dolorosa's* blue vector Recurrence Plot, thus requiring a different symmetry design. Instead of determining points to construct a lattice type, which is a rather normal approach for periodic tiling, the RGB Recurrence Plot present a clear reflection line along the diagonal. I was inspired to use the symmetry group of frieze $F2^2$ with the symmetry becoming more obvious if color threshold adjustments in the Recurrence Plot are made.

The symmetry grouping from the first phase space portrait to the second is a transformation from the symmetry group of ornaments to the symmetry group of rosettes and to the symmetry group of frieze. The second phase space portrait as discussed here focused on the frieze as another type of symmetry in ornamental art which could also be motivated from a Recurrence Plot that showed bounded patterns. A parallelogram lattice was constructed from the RGB Recurrence Plot which served as center points for a p1m symmetry group or $F2^2$ type frieze. In both these groups we have a translation and a reflection across a horizontal mirror. Given the basic pattern, it is just a matter of reflecting and translating the patterns to infer geometry for the remaining regions in making the frieze symmetries move in one direction.

I printed the frieze design as white guidelines on the RGB Recurrence Plot. I used this method to facilitate the copying of the design onto the glass. This also helped determine the areas to be gilded, engraved or etched with the colored Recurrence Plot visible underneath. Only gold leaf was applied in the work and green glass of 3/8" thickness was used to emphasize the distance between the gilding on the surface and at the back of the glass (see Figure 5).

*Figure 5. Engraving and gilding on glass and the finished Signal No. 2 (RGB).*

While the first phase space portrait explored the symbolism of geometries and the visual connection with the *santo's* motif and color, the second phase space portrait explored the design of a symmetry group of frieze. Gilding techniques were extensively explored in the second work, with applications on the glass and on etched areas beneath the glass. I applied reverse gilding on large areas of the glass, as well as engraving work on the back. An interesting texture of layers resulted by the lighting of the work from behind, where etched areas blurred certain areas of the Recurrence Plot, and shadows were cast by the engraved lines and gilded areas.

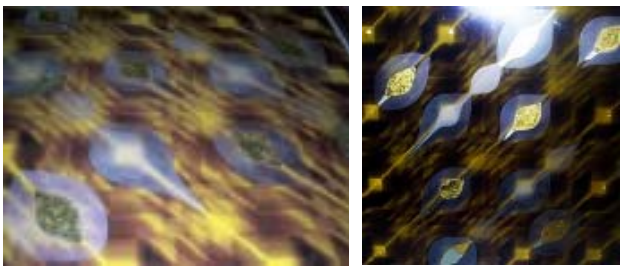

*Figure 6. Engraving and gilding work on Signal No. 3.*

For the third phase space portrait of the *Dolorosa*, I used the red vector in producing the Recurrence Plot. I experimented with various settings with the software in generating the Recurrence Plot until an interesting pattern appeared. The pattern especially became distinct when I used the Lyapunov Color map.

The third phase space portrait entitled "Signal No. 3 (Red)" consisted of the unbounded symmetry patterns revealed by the Recurrence Plot. This time, I followed the curved lines of the Recurrence Plot rather than the straight geometric lines made by marking lattice point on the pattern. Engraving lines were flowing and etching and grinding work departed from the uniform texture of the previous works, now fibrous and ductile, establishing variational values rather than flat frosting.

The red vector Recurrence Plot exhibited a pm type, with two reflections and a translation, and could also be classified as a p1m type, two non-perpendicular translations. While the blue vector used in the first phase space portrait exhibited a primitive cell with the possibility of a rotation, the red signal offered a more rigid translation with a lattice type of square. However, the embedding values and the color map used diminished the rigid pattern of the Recurrence Plot where areas of similar color are not sharply defined, blurring boundaries between the image's trajectories.

While in the first two works I emphasized on geometric form, in the third I look into the biomorphic. Engraving and etching techniques used played up this plasticity to demonstrate that con-

structions from Recurrence Plots need not all be crystallized geometric form. With colored glass explored in previous works, clear glass is used and gilding techniques using gold and silver are applied without the rigid boundaries between the areas of their application. Gilding, this time, is used like paint, like reflective color of two distinct hues - gold and silver. With this symmetry covering the plane, the uniformity is broken by the use of gilding and etching techniques intended to conceal and reveal seven areas within the composition - seven areas that correspond to the seven sorrows of the *Dolorosa*.

As earlier mentioned, the three phase space portraits, consisting of layers of glass and backlit film prints stretched between acrylic plastic sheets, were mounted with stainless steel frames. Through consultations with glass and stainless steel fabricators, I was able to design a frame consisting of two L-shaped frames, one supporting the front of the work and the other, a smaller frame, to support the back. The three works were then bolted on steel brackets fastened to the wall, with fluorescent lighting installed at the back.

## 4. CONCLUSIONS

This paper presents ways by which the use of the mathematical concept of Recurrence Plots have assisted in determining the coloring of patterns and the design of planar symmetry for three phase space portraits of the *Dolorosa*. By digitization, the additive color signals of an image of the *Dolorosa* were processed to yield patterns by which symmetries were motivated. This study also showed that random or chaotic signals can produce regular patterns, thus providing a new method for pattern formation that artists can utilize. By producing the works that investigate these ideas, this study showed how aesthetics and mathematics converge using analog and digital materials and processes in producing images that represent concepts of the spiritual and the divine. The use of software that explore the importance of Recurrence Plots as visual qualitative analysis tools deserve further investigation by artists who seek new modes of creating new images.

Through this study, my love for art, cultural heritage and computers have resulted into a work that has also enriched my experience with the language of mathematics. We know art does not flourish in a vacuum and in this case the speculations of contemporary physicists and works of modern mathematicians become essential factors in the thinking of contemporary artists. As Max Bills posits in his "Mathematical Approach to Art," here is how art is daily creating new symbols: symbols that may have their source in antiquity, but which meet the aesthetic-emotional needs of our time in a way hardly any other form of expression can hope to realize.

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