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# ARCHITECTURE, MUSIC AND PATTERN RECOGNITION THE CASE OF ANDALUSIAN ARCHITECTURE

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***Abstract*—The aim of this ongoing research project is to reach a pattern recognition process (design system) that can turn architecture to music, and turn music to architecture. . In both operations, style and character will be an essential issue in the design of this process system. Based on the artistic relationship between architecture and music, we shall try to settle a mechanism for a pattern recognition audio-visual system that can that can turn a certain style of architecture to a collection of melodies that truly reflects the character of that architecture. This system can also perform the inverted process that is turning a certain musical style to a collection of shapes and forms. In this regard it is important to point out to the inter-relationship between the architectural design process and writing a musical note. A musician composing a melody works from above, that is from the whole to the parts. A composer does not usually put notes together in order to get some melody; he envisages the character of a melody in a *statu nascendi* and proceeds from above as he tries to concretize it in all its part. In this respect, the articulation of the whole and the important junctures of the parts, the beginning(s), or the end(s), the composer accepted the attitude of his contemporaries, and could therefore integrate principles of architecture such as the golden section and the Pythagorean Theorem, along with principles of acoustic harmony. The melody steps of these musical golden sections (time-space intervals of varying scales) can follow the rules of the Pythagorean Theorem. Originality in expression does not depend on invention of new words; nor originality in poetry on invention of new measures; nor in painting on invention of new colours, or new modes of using them. That means that innovation and creativity is a matter of "relationships". In architecture relationships exist in two ways, in the environment itself, and in the individual's ability to understand and relate to them. They exist at a real, concrete level where the individual is aware of them through his senses, perception, hearing, touching, etc. And the also exist at an abstract or conceptual level in the actual object. They cannot be seen or heard even though the can be described. At the end we are referring to "linguistics" as a platform that can consist architecture and music i.e.: a perceptual or surface structure and a conceptual or deep structure that combines both architecture and music. Architecture and music share the unification of three realms: conceptual, objectual and perceptual. In the historical writings of *ikhwān al-safā*; (*The Brethren of Sincerity*-Muslim philosophers in Basra, Iraq, in the 10th century), the relationship between arts, architecture, music, astronomy, mathematics and chemistry was clearly mentioned. In this paper we had chosen Andalusian Architecture as a part of Islamic Architecture that existed in Spain (AD 711-1492). Also there is a significant retrieving and re-composing for Andalusian music prepared by Al Rahbaniya in Lebanon in seventies of the 20th century, also Andalusian music is still played in Morocco, Algeria and Tunisia.**

***Index Terms*—Pattern recognition, music, architecture, genetic algorithms.**

## I. INTRODUCTION

In the Arabian schools in Andalus the art of organizing was taught, as we know from a contemporary Spanish chronicler, Vergilius Cordubensis. Mensural music was known to the Arab theorist Al-Khalil (d.791), but his *kitab al "iqa"* (*Book of Rhythm*) has not come down to us. It was known to Al-kindi, to Al-Farabi. In 1252, Safi al-Din al-Urmawi developed a form of musical notation, where rhythms were represented by geometric representation. Al-Urmawi's most important work are two books in Arabic Language on music theory, the Kitab al-Adwār and Risālah al-Sharafiyyah fi 'l-nisab al-taʾlifiyyah. The Kitab al-Adwār is the first extant work on ***scientific music theory*** after the writings on music of Avicenna (full name Abū ʿAlī al-Ḥusayn ibn ʿAbd Allāh ibn Al-Hasan ibn Ali ibn Sīnā= 18 June c. 980 – 16 August 1037). It contains valuable information on the practice and theory of music in the Perso-ʿIraqi area, such as the factual establishment of the five-stringed lute (still an exception in Avicenna's time), the final stage in the division of the octave into 17 steps, the complete nomenclature and definition of the scales constituting the system of the twelve Makams (called shudūd) and the six Awāz modes. It also contains precise depictions of contemporary musical meters, and the use of letters and numbers for the notation of melodies [10]. ***It is the first time that this occurs in history***, making it a unique work of greatest value. Al-Urmawi's 'international' modal system was intended to represent the predominant Arab and Persian local musical traditions [16].

## II. METHOGOLOGY

### *A. Analyzing cognitive features*

We will discuss the neural basis of acoustic cognition and emotion that is music. The primary input for music is of course

the acoustic signal. Our understanding of the auditory system is however far behind that for vision in which the neural basis of processing of shapes, colors and movements of visual objects have been studied in great details. Music is not just an acoustic experience. Like all other artistic human activities, it recruits multiple systems dealing among others with emotion, movement and possibly language [8]. The neural manifestation of these systems is activity in limbic structures, higher motor cortical areas and neocortical association areas. We attempt to elucidate interactions among regionally specialized neural sub-systems responsible for the human perceptions of music, cognition, emotions and action (dancing).

"Figure 1" shows the flow of visual (to the left) and auditory (to the right) information in the cerebral cortex. Originally the dorsal and ventral pathways were referred to the neuronal paths within the posterior association cortex. These terms are used here to extend the routes to and from the prefrontal cortex. Correlation with motor-related domains is included in the diagram. Brain Data in the form of tensors (multi-mode arrays) are becoming very promising in the data mining and information retrieval in the last few years.

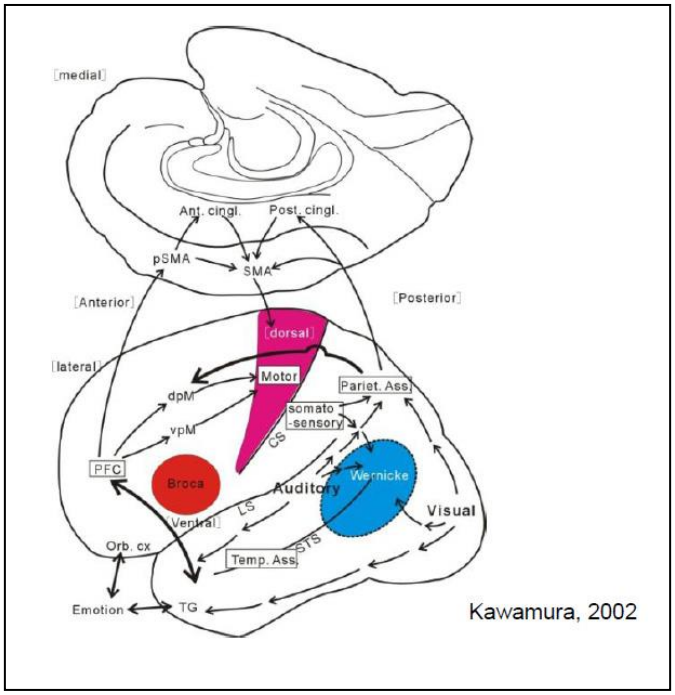


**Fig. 1. Brain Data in the form of tensors (multi-mode arrays)**

Electric signals are degraded into each element in different parts of the brain in which different neuronal groups are composed and there, each information is analyzed and treated with in parallel ways, and as a result, cognitive features are integrated as a form or Gestalt. In addition, the visuospatial and sound-spatial or grouping function are included in the dorsal path, while the emotional function are included in the ventral path [7].

The effort to reduce certain sound sensations, to understand their logical causes, to dominate them, and then to use them in wanted constructions; the effort to materialize movements of thought through sounds, then to test them in compositions; the effort to understand better the pieces of the past by searching for an underlying unit which would be identical with that of the scientific thought of our time; the effort to make "art" while "geometrizing", that is, by giving it a reasoned support less perishable than the impulse of the moment, and hence more serious, more worthy of the fierce fight which the human intelligence wages in all other domains - all these efforts have led to a sort of abstraction and formalization of the musical compositional act.

*B. Defining and selecting feature based generators*

Architecture and music share three main generators features "Fig. 2". To facilitate a feature-based interface, a more abstracted music representation system is needed. This system describes music sequences as a fluctuating set of parameters, each of which corresponds to some salient musical property. This set of parameter data, is the parameter-space equivalent of the input sequences; it will contain all of the information necessary to regenerate the original sequence [6]. The benefit of this design is that any of these parameters can then be manipulated in real- time to dynamically shape features of the music being generated. Regarding the feature-based analysis for music, we the following main generators:

***Rhythm,*** Arabic notion of maqam involves implicit rules for melodic/rhythmic generation on the scale structure. The elaborated meaning and function of a maqam are hypothesized to appear in the form of conceptual, symbolic mental representations, in generative schemas and cognitive frameworks adapted to the development of the phases of modal improvisation.

***Melody,*** Arabic melodies draw from a vast array of *melodic*, known as *Maqamat* (singl. *Maqam*). Arabic books on music include as many as fifty-two melodic modes, of which at least twelve or so, *are commonly used (rast, bayati, hijaz, huzam, saba, nahawand, kurd, sikah, nakriz, suznak, ajam, hijaz kar Kurd, and Farhfza). These modes feature more tones than are present in the western musical system, including notably smaller intervals that are sometimes called microtones, or half-flats and half-sharps.*

*The tonal system of Maqam is based on a two-octave (Diwan) fundamental scale. In addition, the central of octave notes are named Rast, Douka, Sika, Jaharka, Nawa, Hussayni, Awj and Kirdan*. Modulation is a method and a technique used during the melodic development of the *Maqam*. It consists of playing one or more notes outside the scale of the *Maqam*, in order to produce a second known *maqam* that is compatible with the first one. Modulation can carry on by transitioning to anther Maqam or Maqamat, and usually returns to the starting Maqam. In the Taqasim or the tahmelah, Arabic musical forms with free rhythm; the soloists can modulate quite a few Maqams.

***Chord,*** The scales underlying a given maqam are most commonly organized in terms of series of 4 to 5 pitches, called tetra chords and pentachords, respectively. In Arabic, such a cell or genre is called ıqd (plural uqud) or jins (plural ajnˆas). The basic cell that is joined with others to create maqamat is the jins, which is a tetra chord or pentachord, and more rarely a trichord. There are 9 to 11 commonly recognized ajnˆas that are distinguished by their interval structure and the note upon which they are traditionally based [2].

Architectural generators are classified in "Fig. 8" according to their mental processes involving analysis and condensation. Cultural sensitivity, field of knowledge and the experience of the architect-composer will decide at which this process of conjectures and refutation can take place.

| | Architecture | Music |
|---|---|---|
| Generator 1 | Order | Rhythm |
| Generator 2 | Space | Melody |
| Generator 3 | Materials | Chord |

**Fig. 2. Architecture-music feature based analysis, source: author**

## III. Fingerprint Extraction

Concerning the basic set of musical features, the Gaussian triad are the preferred ones, followed by rhythm and intensity. Arnold Schoenberg (1874 - 1951) experimented with a system with a strong geometric form. He defined a 12-tone system for music. Actually it was in 1252, when Safi al-Din al-Urmawi developed a form of musical notation, where rhythms were represented by geometric representation [10]. In his work on scientific music theory the complete nomenclature and definition of the scales constitutes the system of the *twelve Makams* (called shudūd) and the six Awāz modes "Fig. 3". the maqˆam is a recalling of a cultural identity, a modal system, and a form of improvisation. It forms an organic whole comprising a characteristic scale (with substitutable jins), but above all a set of conventions theoretically allowing it to be

easily identified, whatever the variations to which it is subjected by the performers [9].

Through deep analysis of 2D Islamic patterns we see the same *twelve-square* arrangement shown as a harmonic growth pattern which can be taken as a master diagram, or archetypal proportioning diagram, used by the craft schools of Islamic art down the ages, to demonstrate controlled proportional decrease or increase; in this the very smallest circular arrangement of *twelve squares* relates proportionally by nine stages to the largest outer group. Viewed in this way, this diagram can provide, by harmonic diminution or augmentation, a proportional guide for the design of an entire building or a single tile [15].

In Islamic Architecture, the unfolding of the geometric laws in the realm of mathematics has a quality corresponding to the unfolding of both consciousness and creation itself. With the certainity of the one source and the primacy of the archetype of three, four, seven and twelve we will recreate the basic patterns. Islamic artist was not only versed in mathematics in the geometrical sense, but that mathematics was integrated to his art as it was a universal structure supporting the intuitive insights that characterize all true art [3].

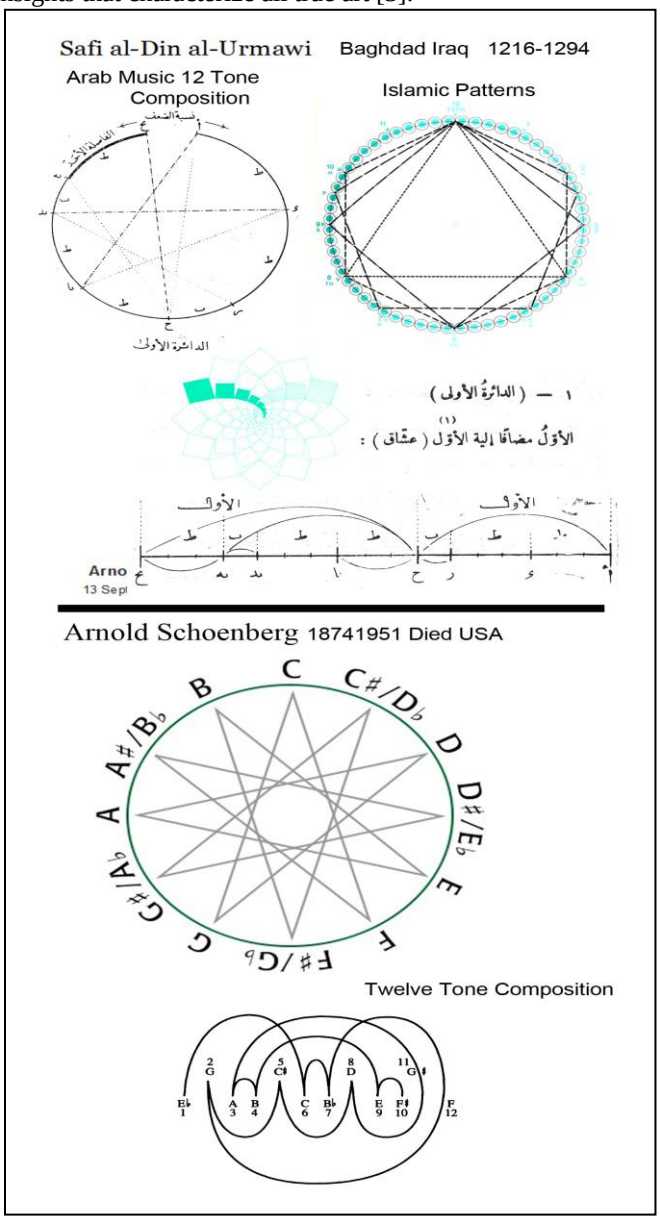


**Fig. 3. Music, mathematics and geometrical representation**

## IV. SHARED PARAEMTRICS

The early theory of classical Arabic music is that of the mizan of Arabic poetry from which music making developed as an orally transmitted (i.e., undocumented) art form. The cultural exchange in the Muslim world established this theory as the common basis of independent music making also in Persia, Turkey, and North Africa [14]. Europe for a long time followed the Greeks in recognizing only the 8ve, 5th, and 4th as consonance. The 3rd was banned as a dissonance. Yet Al-Farabi (tenth century) and Ibn Sina (eleventh century) recognized the *Major Third* (4:5) and the Major Third (5:6) as consonances, whilst Europe was holding to the dissonance of the Pythagorean Thirds (64:81 and 27:32). The Arabian pandore (tanbur al khurasani), which became very popular in in Europe, gave a close a close approximation (6561:8192) to the Major third (4:5), and one may conclude that it was by these means that Europe first became dissatisfied with the Pythagorean thirds and adopted the new ones, although the were probably only admitted as consonance *in organum* much later.

From a mathematician's perspective, music is nothing else but a sequence of numbers (frequencies) which are related to each other according to some certain proportions. However, we believe that this does not reduce the value of a musical score in any way. Instead, it shows that the notion of proportion is essential for euphony, and more generally, that mathematics is the key to understand harmony and beauty.

Islamic geometric art consists of complex geometric patterns which demonstrate us the mathematical level of the Islamic world. Though its roots are in Byzantine and Roman geometric decoration, Islamic geometric art has created a complex and authentic language of its own. Through these patterns, the ancient Islamic artists raised the visual expression of geometric figures to a very high level [15]

Islamic geometric patterns are one of the most beautiful instances of the combination of mathematics and visual arts"Fig. 4" . For instance, the mathematical properties of those patterns are examined by crystallographers, since these patterns have similar constructions as the crystals [1].

In addition, modern mathematicians studied these patterns under the category of tessellations. Even though ancient artists created Islamic patterns for mainly artistic reasons, modern science is recently discovering many other features of these patterns, and these studies are abundant resources in the exploration of the question how to combine visual arts and mathematics through Islamic geometric patterns.

Mathematics and science had influenced arts from ancient times: e.g. façade of Parthenon built in the fifth century B.C. contains a number of proportions such as the golden ratio andmthe square root of 2, while periodic pat-terns frequently occur in Islamic and Andalusian ornaments.

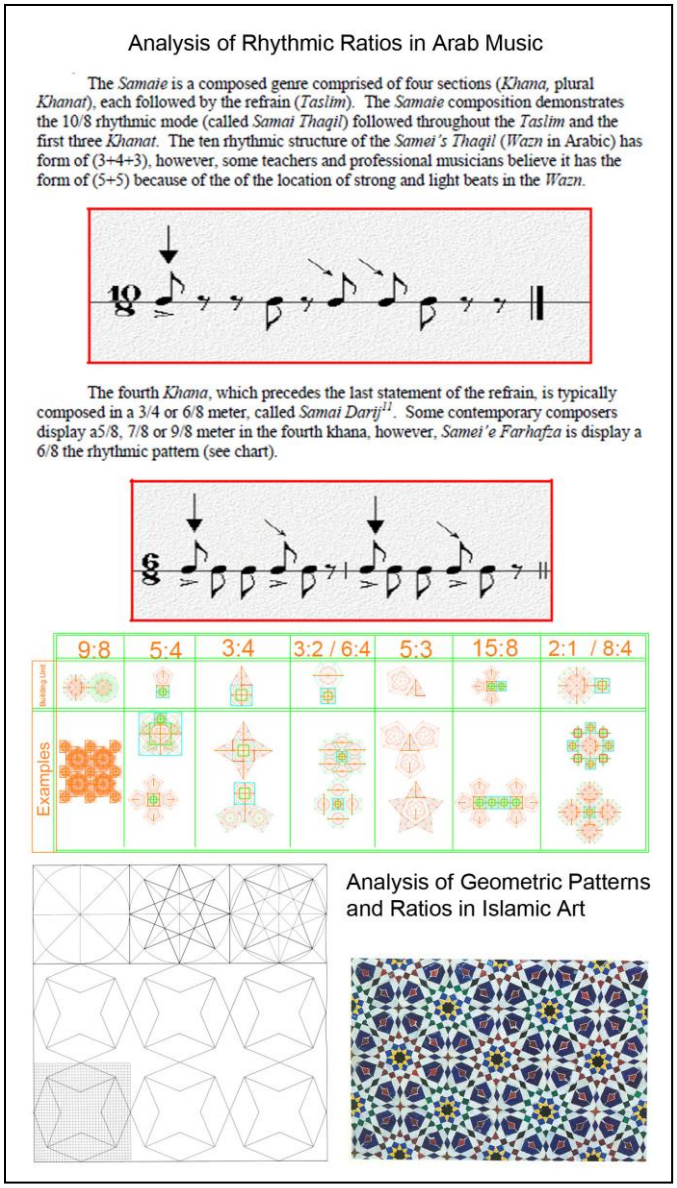


**Fig. 4. Shared ratios between Islamic geometric patterns and rhythmic structure in Arab music, source: author**

Creating of artworks is not (only) an intuitive activity related mostly with emotions and inspiration. During the history of art numerous techniques were devised in order to make the faithful representation of objects or to obtain particular artistic effects.

Development of computer technology and particularly graphic cards and software in the second part of the 20th century made an enormous influence on the ability of visualizing mathematics and using these visualizations in design and art.

One of the best known mathematical approaches created in the era of computer graphic and exceptionally suited for generating attractive visual structures are fractals, a family of self-similar (they appear similar at all levels of magnification) and scale invariant objects that have a simple recursive definition. It was in the 14th century when the architects and artists of the Alhambra in Al-Andalus the type of aesthetic morphology is defined by the nature and content of its matter and the mood of spreading of this matter within space "Fig. 5".

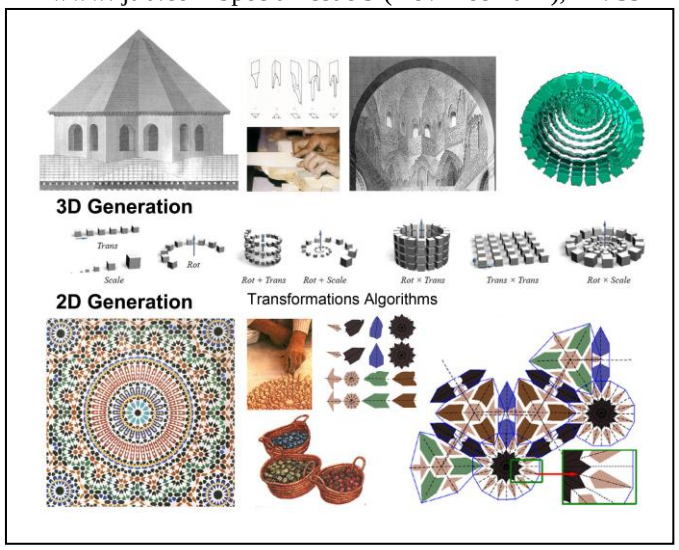


**Fig. 5. It is within the subjective space of the aethetic experience that the things seen (the architectural forms) and the things known (the epigraphic content) truly articulate themselves, source: author**

## V. Pattern Recognition Through Genetic Algorithms

Pattern recognition is a field in statistics whose aim is to recognize sub-patterns within a big amount of data. It entails extracting the most relevant information associated to those patterns, which allows the classification of new data. It is the implementation of an automatic way to generate several features. Feature mining can be a troublesome and time-consuming task. We might never find good features if we do not automatize the search. Genetic algorithms are therefore desirable, in that they provide flexibility and systematization in the process. Evolutionary algorithms are traditionally used to solve optimization problems. In addition, they can be used as a design aid. The evolutionary approach is a generative testing method that fits the procedures for design synthesis and evaluation in the design process. The characteristics of the approach are: A pool or population of design solutions, rather than a single solution. The selection of individuals according to their adjustment to the fitness function. The generation of new solutions through mutations and crossovers of previous elites [5].

Algorithms, mathematics and art are interrelated in an art form called algorithmic art. Algorithmic art is visual art generated by algorithms that completely describe creation of images. This kind of art is strongly related with contemporary computer technology, and especially com-puter programming, as well as with mathematics used in algorithms for image generation [4]. Given a certain database with small music extracts and simple labels (happy, angry, scared, sad), it would be interesting to look for features that best correlate to emotions in music. During this ongoing research, such a database is not yet found, but both fields –architecture and music-are getting closer and closer, and it might be easier to find it in the future "Fig. 6". Our final suggestion for the future is the implementation of an automatic way to generate several features. Feature mining can be a troublesome and time-consuming task. We might never find good features if we do not automatize the search. Genetic algorithms are therefore desirable, in that they provide flexibility and systematization in the process [12].

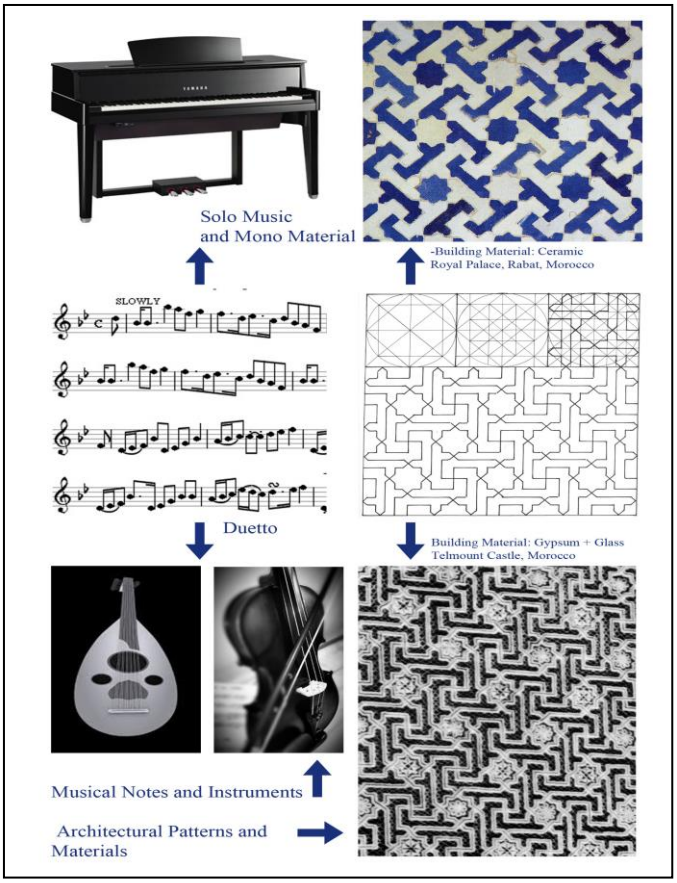


**Fig. 6. Architecture and music- a close relationship in their shared genetic systems, source: author**

Various algorithms are used for producing computer drawings of the Mandelbrot set. They are quite simple, and e.g. the so called "escape time algorithm" has only about a dozen of steps. This is a good example of a simple mathematical model generating complex results.

Some of the other mathematically based methods used for generation of attractive images are genetic algorithms and cellular automata [11]. Automata are also used for generation of random numbers for the Mathematica software, which is again an excellent example of complex structures generated by a simple algorithm.

Algorithmic art is based on generation of visual artworks using algorithms, i.e. precise defined procedures that computer executes step by step. Algorithms are implemented in computer programs coded in some programming language. Algorithm, or computer program implementing it, describe the process of generation of image that we can see either on the screen or as printed. Program for image generation contains the author's idea about the image as well as the technique by which this idea is transformed into an image. It also has to define which graphical elements and their structures that should be generated (straight or curved lines, shapes, a group of elements with a specified structure, etc.), what are values of their parameters (e.g. position of a rectangle, its dimensions and its elevation toward axes), colors of lines and shapes, etc. Algorithms use computational structures such as loops, subprograms and recursion, as well as various mathematical expressions [13].

Since algorithmic art consists of generation of images on the basis of algorithms, algorithms can be viewed as a notation, and notation is something that music has but visual arts in general miss. There are further parallels of algorithmic notation with music

Much of the art of Islam, especially architecture, is characterize by its feature-based consistency of transformation. Essentially, this is a reflection of the Islamic preoccupation with the transitory nature of being. Islam's concentration on geometric patterns draws attention away from the representational world to one of pure form, posed tensions and dynamic equilibrium, giving structural insight into the workings of the inner self and their reflection in the universe "Fig. 7".

Algorithmic art itself, a discipline that unites mathematics, computing and art, has a rather specific character since the author has to possess rational abilities required to compose the algorithm and write the corresponding computer code. Within this ongoing research we are seeking to develop a unique technology based on tensor factorizations. Data are collected in the form tensor and decomposed into spatial and time frequency components. This allows us to estimate and extract components and features corresponding to specific mental tasks, emotions and music perception. Additionally parametric representations in different mediums would promote inter-medium communication. Perceptual variables in a music system might be mapped to perceptual variables in an animated computer graphics system to construct a sort of synthetic synaesthesia "Fig. 8".

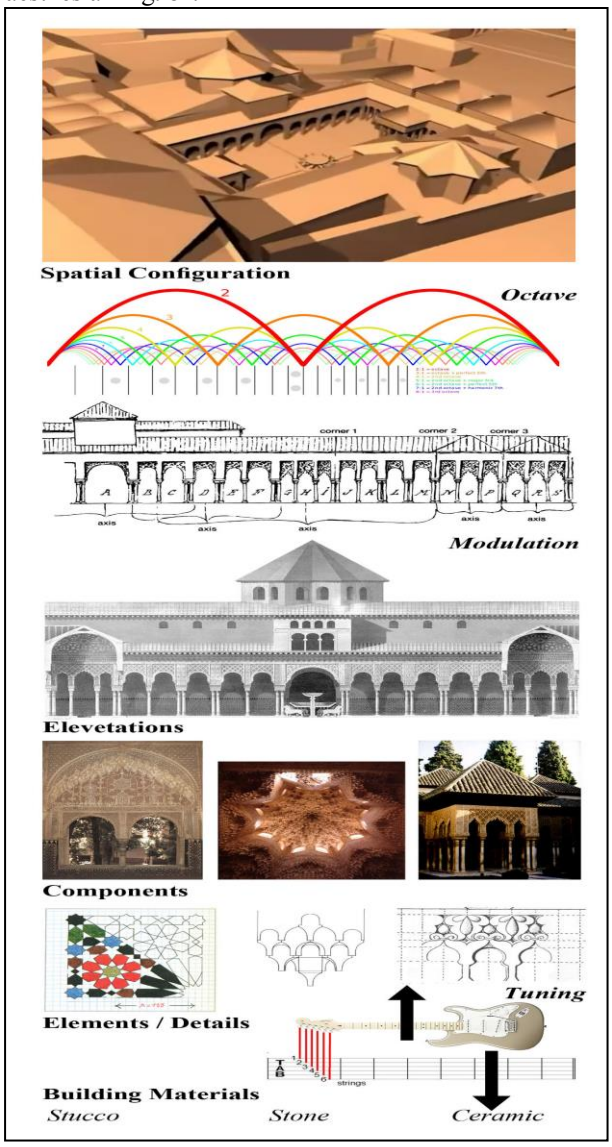


**Fig. 7. Morphological analysis for different layers in the design process of the palace of the Alhambra in Andalusia, Granada, Spain (1333)**

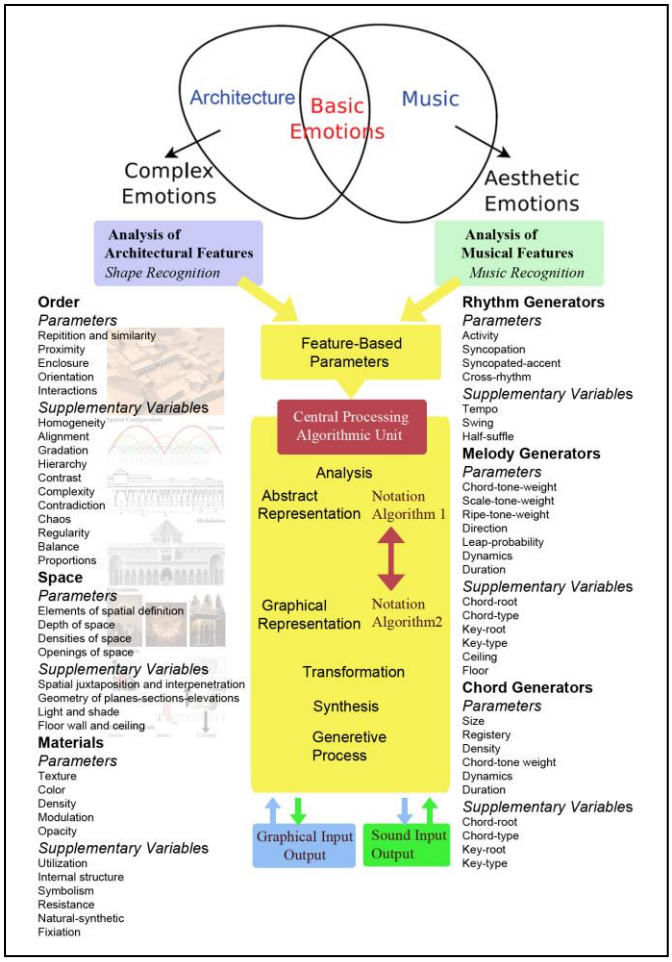


**Fig. 8. A comprehensive frame-work for the transformation between Architecture and music based on their genetic algorithms, source: author**

## VI. Conclusion

Within this ongoing research, we are seeking an application oriented to a digital graphic art system. An artist, musician and an architect, will begin by seeking some primitive graph materials. Salient properties of that image (color, texture, shapes) could then be freely manipulated. Dozens of complex, transformed images could be quickly generated allowing the artist to rapidly navigate and recreate through a landscape of audio-visual aesthetics.

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