# SYSTAB: A PROACTIVE REAL-TIME EXPERT SYSTEM FOR ANCIENT GREEK MUSIC THEORY AND NOTATION

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## 1. INTRODUCTION

When studying the corpus of ancient Greek music theory and related literature [1], one invariably finds oneself confronted with references to a multiplicity of 'scales' (nomoi, harmoniai, systēmata, tonoi) and diverse shades (chroai) of tunings. During the dawn of European science, epistemological considerations of the phenomena of pitch and harmony played a major role and acted as a sensually accessible, quasi-experimental match-maker of later on diverging fields of knowledge and methodologies. Disputes about the right way approaching pitch in general and how to systematically deal with fine pitch variations in particular are legend [2], latest since Plato's famous metaphor of vexing and torturing strings on the rack [3, Politeia 530d—531c] and Aristoxenus rejection of musical notation (parasēmtikē technē) as mere eye candy [4, 49.16—50.18]. Besides the instrumental re-production and subjective acoustical comparison of pitched sounds (phthoggoi), diverging methods based on different scientific media like numbers, diagrams and specially designed signs were used to analyse, to theorise and to encode phenomena bestowed by the muses that we are used to call 'music'—still at this joined conference.

## 2. MEDIA AND UNDERSTANDING

Yet, as the living musical tradition that gave rise to these most original forms of representing pitch, tonal structures and melodies was already gone for to act as a acoustic corrective, modern researchers, Byzantine archaeologists and even scholars in later antiquity were struggling with the epistemological but likewise media-induced gaps left between their enactments. Hence, each of the major historical 're-visions' come up with their own 'solution' of how to deal with the diverging approaches. Just to name the most telling ones: (i) Ptolemy devised his famous re-tuning machine, the helicon, made in order to easily display mathematical fractions and to experimentally shift a whole set of pitches proportionally [5]; (ii) the Byzantines employed dynamically tuned pitches, a practice already inherent in the ancient scalar system [6, p.361—371], but although recycling its terminology, they nonetheless developed a completely new form of music notation; whereas (iii) the nineteenth century musicologists, Bellermann[7] and Fortlage[8] with their attempts to decipher and to transcode the ancient notation system into the then prevailing western one, forcefully squeezed its original systematics within the all too 'natural' circle of fifths by inventing an extended set of accidentals which finally did not fit that well and which could only be justified, if assuming a by now disproved [9][10] diatonic origin of the ancient notation.



## 3. A UNIFYING MEDIA APPROACH

### 3.1 Recent systems addressing ancient Greek music

The present demonstration proposal of an expert system for ancient Greek music (AGM) theory and notation could be regarded as yet another attempt in this scholarly tradition on solving the legendary dilemma presented by the sources. In particular so, as similar appearing systems have already utilised potentials in multi-media formats and interactive sound-synthesis for educational and compositional purposes [11] as well as for archaeomusicological research proper on ancient Greek scales[12] and organology [13][14]. With each of them, however, interaction becomes strongly streamlined, perspectives on pitch and scales get limited to a certain representation, and mappings to notational symbols or diagrams, if any, turn out to be fixed to a specific historical model and insensitive to any harmonic or melodic context.

For instance, ARIŌN, while claiming to be the first notation-based AGM editor, composer and synthesizer of its kind [15, p.478], unwarily repeats what Bellermann and Fortlage did, in that it maps Greek instrumental and vocal notation symbols to a western stuff notation interface, in a way well known from mainstream sequencers like Cakewalk or Cubase. The follow-up "multimedia application", ORPHEUS, designed to be a "virtual learning environment" for AGM [16, p.295], still has no sensible interface to tunings. The trademarked Virtual Lyre™ [17], on the other hand, an earlier "developed" sound-synthesis application with a graphical user interface patched together from standard Reaktor™ components, was specifically devised for "hearing Greek microtones" of different tetrachord divisions [12] and for "audio-demonstration[s] of harmonic and resonant phenomena" as known to the Greeks [17], but makes no attempt on representing scales as diagrams or by notation.

### 3.2 A cardinal challenge

Unifying the different forms of representations, however, not only poses technical questions for a suitable interface design but also reveals a more principal challenge pointing at the epistemological heart of Greek harmonic science and to the core problem of any true scholarly engagement with ancient Greek music. This can be understood with respect *of* history and evinced with respect *to* the development of scalar constructions, because "in many cases the unequivocal note names were preferable over the signs, ambiguous as these were in respect both to pitch and to musical function"[10, p.3].

Acknowledging this fundamental finding, it appears inescapable for any attempt on clarifying the actual relation of pitches, scales, note names and signs that one has to refer to diagrams which then need to match the different forms of musical representation to each other—always anew for any given context. But even when managing a reconstruction of ancient multi-key diagrams and a subsequent mapping to notation [18], reading such diagrams can be intricate and tricky, even to the expert. As a result, the proposer himself feels compelled to give out warnings about the suggestive validity of these diagrams, since "to find the pitch relation of any two signs of different keys, one has to determine first the interval of one of these to a fixed note (if it is not itself one), assuming a specific tuning, then follow the path of tetrachords and whole tones to some fixed note of the other key, and then to the note in question there". [10, p.12]

The only way out making these pathfindings transparent and acoustically sound seems to rely on bringing some sort of a 'living-diagram', or more fancy perhaps, a pro-active real-time notation system to the table.

### 3.3 Turning the tables

The drama of representing music cannot be solved, but might only be staged. This general assertion—necessary to be outspoken at a conference in Athens—can be narrowed and specified, if scientific concepts and historical media of ancient Greek music are laid on the table. In this audio-visible case of theorising, however, the proactive deus ex machina is no spectacular invention of a modernising Euripidēs—essentially terminating all tragedy—but on the contrary, the embodied metaphysics of the 'trans-classical machine'[19, p.179] now running on everyone's desktop. This entails that, on the one hand, while potentially simulating all machines stemming from Archimēdēs, or better said Archytas[20, p.328—337], the current media upheaval irrevocably divides our present Turing Age from the Tragic Age but, on the other hand, it nonetheless reconnects us anew in not yet fully understood ways with the virtual essence and strict logic of Greek drama [21, ??].

In any case, one valuable characteristic of the non-trivial machinery at hand today is the pro-active ability to carry out a multitude of complex reasoning and to offer the results as potential alternatives in due time while we are still thinking. Thinking, thus, of the cardinal pathfinding challenge above, alternative pathways through the Greek web of scales may be calculated either on demand or automatically while we are still learning, reflecting and discussing or, right on the moment, when we are listening how a melody unfolds.

This practice of transparently changing perspectives on representations of music at any time, or pre-emptively in the background, can be regarded as the core motivation and essential distinction of the present approach. Metaphorically it may be imagined as proactively 'turning the tables' on ancient Greek scales (systēmata) and shades of tuning which finally led to the current systems' naming as 'Systema Tableau', or in short, SYSTab. As a sensually accessible study tool, while aiming at dynamic perspectives and adaptive tuning, SYSTab may re-enact the diachronic dilemmata and 'aporiai' of ancient scientific concepts, or it may synchronously trace the 'peripeteiai' of modulating melodies on archaeomusicological grounds. In this respect, when visually demonstrating harmonic bifurcations and acoustically revealing turning points of melodies, the unifying media approach of an analytical multi-perceptiveness ultimately becomes a kind of staging of music theoretical and notational scenes.

## 4. SYSTEMA TABLEAU

### 4.1 Overview

At present, the system is build on SuperCollider[22]. It consists of a collection of newly written classes and class extensions, some of which will be touched upon below. After some experimentation, the conveniently accessible, since now directly linked, Qt framework turned out to be a fast enough graphic rendering target for all basic diagram drawing and user screen interactions. In addition, and in order to meet the challenges of the approach describe above, some famous key concepts of SuperCollider were adopted and, where necessary, extended. Although these choices make the current implementation of the system dependent on SuperCollider, it shall be pointed out (i) that the dynamic requirements of the approach virtually asked for an extensive use of functional programming techniques and (ii) that since the interpreter supports lambda closures as first class citizens [23] two further things follow: (a) that the system could still be designed with portability and live-coding purposes in mind, (b) that SuperCollider's general-purpose and multi-paradigm language proved once more to be efficient and flexible enough for scathing domain-specific applications with an open just-in-time programming interface—which, in sum and for simplicity, we call an 'expert system' here.

This is not to say, however, that only skilled programmers can use the system, rather that all visually accessible and changeable objects on screen, like e.g. the intervals of a scale, are reflected in code and always keep being accessible to the language by a coherent dependency framework. In fact, most of the build in functionality for immediate scale manipulation and playing, the triggering of reference tones or the changing of perspectives and representations are exposed to the screen through selecting, dragging, dropping and pulling actions, by contextual pop-up menus or fast, one-stroke keyboard bindings.

Yet, describing all the functions here would be sheer overkill and are better demonstrated at site. Instead, a selection of implementation concepts and AGM domain-specific features shall be listed below.

## 4.2 Implementation concepts

### *4.2.1 scene graph model*

In order to allow for the above mentioned 'music theoretical and notational scenes', all drawing on screen happens by help of a purely interpreter-driven scene graph model. The drawing graph is defined by named proto functions that return the actual drawing functions whenever the graph is asked to be rebuild. The graph is evaluated up- and down-tree by a calculating and an actual drawing pass—indispensable to avoid the 'visibility problem' of the notorious 'painter's algorithm'. Rebuilds can take place at any time and may happen frequently without causing significant overhead. As a result, highly flexible and pretty complex, yet still manageable scenes are made possible.

### *4.2.2 persistence*

Despite of the per-frame flexibility offered by the scene graph model, the state of a SYSTab scene is still persistent. Arrangements of scales, shown annotations, perspectives, zoom-levels etc. can be stored and loaded from disc.

### *4.2.3 live-coding integration*

As the scene graph is basically defined by a tree of lists of symbols referring to proto drawing functions, rearrangements of a scene is feasible by minimal typing and thus in live-coding contexts. Essential run-time programming constructs for algorithmic composition like routines and patterns can easily be used to control what's visible on screen and synchronised with sounds possibly controlled by the very same constructs. Moreover, existing proto drawing functions can be altered, replaced, added or removed at any time, bringing the system close to a general framework for real-time notation projects.

## 4.3 AGM domain-specific features

Taken together, the above implementation concepts provide the necessary infrastructure to principally meet the requirements as resulting from the approach. By manual as well as by programmatic means, they enable for dynamic constructions, arrangements and comparisons of scales and tunings, both visually and acoustically, thereby giving an exhaustive account of the Greek harmonic elements. The latter, however, entail far less regular 'scales' than western, Byzantine or Indian ones and likewise deviate from common collections of microtonal tunings. Hence, in order to finally qualify as an 'expert' system for AGM some extensions of SuperCollider's already rich pitch related classes were inevitable:

### *4.3.1 Systema*

In contrast to its superclass Scale, Systema handles 'non-cyclic' or 'non-octave-indentical' scales. Ancient Greek scale origins marked by a so-called 'middle note' (mesē), are supported by negative scale indices while offsetting the look-up of scale degrees by a positive 'rootIndex'. The notion of a 'tonal center' is introduced by an extra degree, not necessarily part of the scale but certainly pointing to a valid tuning step.

### *4.3.2 Ratio and RCTuning*

Ratios were the mathematicians tool to represent tetrachord and scale divisions in ancient Greece. Since SuperCollider does not support fractions right away, Ratio as a subclass to SimpleNumber has been written.

By means of the RCTuning class interfacing with Systema, rational and cent representations of scales are made persistent and are handled transparently side by side to each other.

### *4.3.3 CodePage*

Experts of AGM would want to define scales right by their native notation symbols. Yet the SuperCollider language cannot deal with expressions containing unicode characters. As a workaround to this limitation, CodePage manages a unicode encoding and decoding of ascii-strings as well as the respective mappings to workable, typically self-made, fonts that would offer the respective notation symbols.

### *4.3.4 SYSAnno classes*

Specific annotation classes help with appropriate mappings of scale degrees to symbols, ratios, cent values, etc. Instances of SYSAnno classes can be stored within instances of Systema, such that scale templates and smart lookups for fitting annotations reduces the effort defining a scale tremendously.

## 4.4 A final example

The old mixolydian mode (here given in the tuning of Archytas) appears as a suitable example to demonstrate many of the features referred to in the previous section. It is fully defined by simply typing the next line and is shown on the Systema Tableau as depicted by the figure.

Systema.archytasStoichos.copyByItems("⊏Ɔ∪CF⅂L", "old-Mixolydian: μιξολυδική ἁρμονία", nil,"<")

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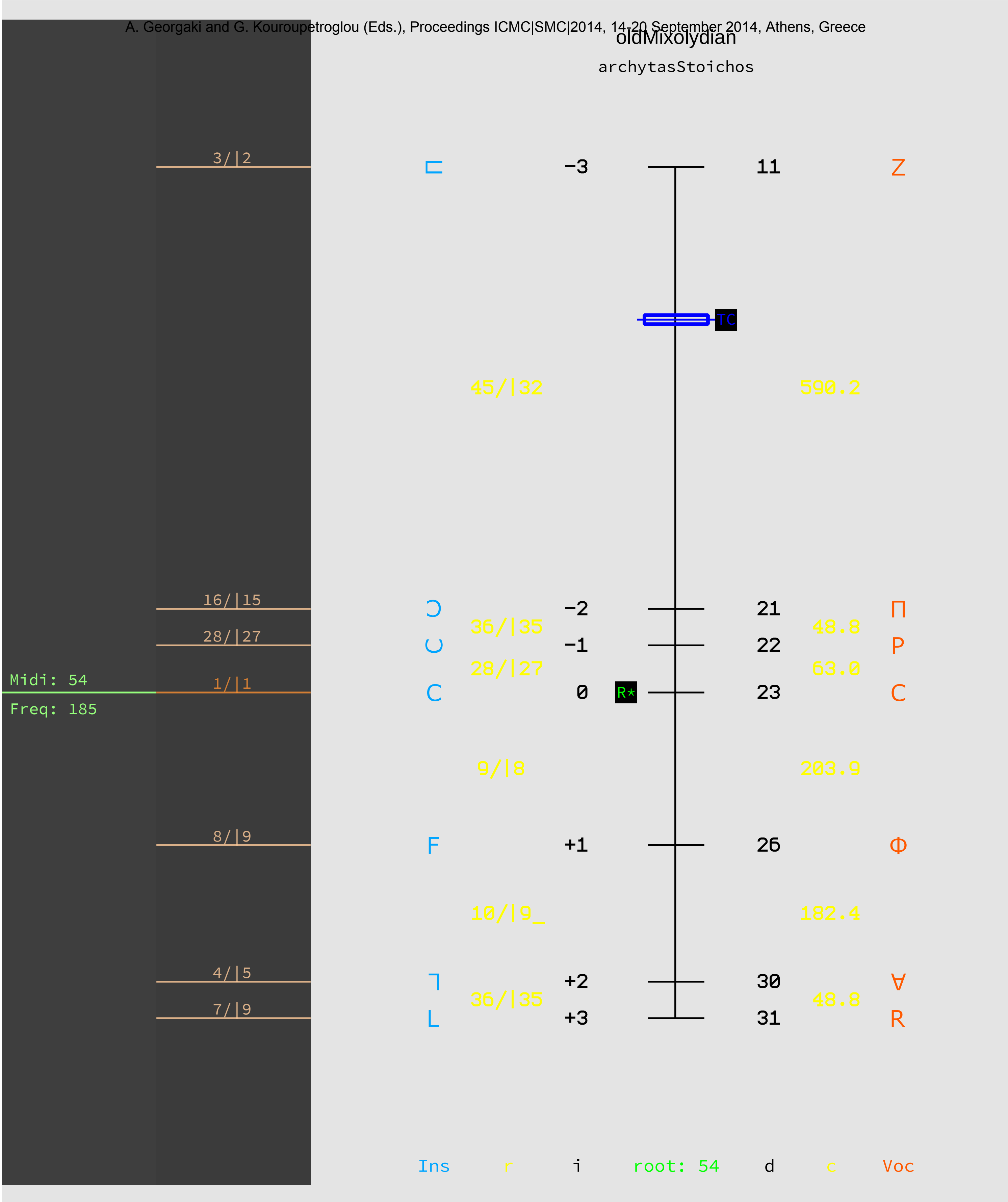
oldMixolydian
archytasStoichos
3/|2
16/|15
28/|27
Midi: 54
1/|1
Freq: 185
8/|9
4/|5
7/|9
-3
11
Z
TC
45/|32
590.2
-2
21
Π
36/|35
48.8
-1
22
P
28/|27
63.0
C
0
R*
23
C
9/|8
203.9
F
+1
26
Φ
10/|9_
182.4
+2
30
∀
36/|35
48.8
L
+3
31
R
Ins
r
i
root: 54
d
c
Voc