THE HOUSE HARMONIC FILLER: INTERACTIVE EXPLORATION OF CHORD SEQUENCES BY MEANS OF AN INTUITIVE REPRESENTATION

Ángel Faraldo, Perfecto Herrera, Sergi Jordà
Music Technology Group, Universitat Pompeu Fabra
name.surname@upf.edu

ABSTRACT

In this paper we present an interactive two-dimensional representation of musical chord progressions, integrated into a computer program that generates house music harmonic loops in MIDI format, based on a user's input. Our aim is to encapsulate relevant tonal information and display it in ways that are easy to understand for novices and untrained musicians, facilitating the creative exploration of musical ideas. We briefly reference previous work on tonal visualisation and interaction, and introduce some measures of tonal properties from the literature. We then present our system and describe the two-dimensional harmonic map, before discussing its outcomes and shortcomings, pointing at future lines of research in the conclusions.

1. INTRODUCTION

Computers have become one of the epicentres of professional music making. This has not only lowered costs in production, but has also facilitated music makers to be in closer contact with –and in many cases, to take complete care of– all stages of the music production chain, including tinkering and brainstorming, composing, layering and editing, recording, mixing, mastering and eventually, performing. Moreover, computers potentially provide a new realm of possibilities to the amateur musician and the curious mind, inviting them to engage in musical creation in unprecedented ways, through a variety of educational tools and games, digital musical instruments and accessible digital audio workstations (DAW's).

In this paper, we introduce a two-dimensional representation of chord sequences, that allows users (especially novices and musicians without formal education) to easily develop intuitions about certain tonal properties, like modality and tonal tension. Our visualisation method is integrated into a simple computer program that creates harmonic loops in house music style, a popular subgenre under the umbrella of Electronic Dance Music. As it will become apparent, house music holds a number of properties that make it suitable for our study.

Our explanation unfolds as follows: in the next Section, we briefly present related work in the areas of pitch space representations, digital interactive systems for harmonic exploration, as well as some existing measures of tonal properties. Then, we proceed to describe our computer program in Section 3, with an emphasis on the two-dimensional interactive space proposed. We discuss its outcomes and limitations in Section 4, before concluding with a summary and pointing at directions for future work.

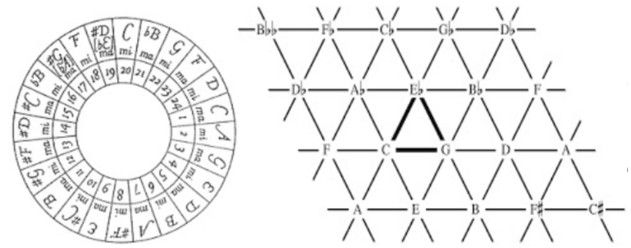

Figure 1. Typical renditions of pitch spaces: the circle of fifths (left) and a simple *Tonnetz* diagram (right).

2. BACKGROUND

2.1 Pitch Space Visualisations

Probably the most widespread representation of pitch spaces is the so-called circle of fifths, which represents relationships between adjacent keys. Richer in its representative power is Euler's *Tonnetz* (1739), displaying other intervalic relationships (major and minor thirds alongside the cycle of fifths), and upon which Riemann's influential tonal functional theory is grounded.

Several other pitch and chordal spaces have been developed since, following similar configurations. The geometrical representations of Longuet-Higgins (1962) and Balzano (1980), which attempt to represent harmonic distance, are worth mentioning, for they have been used in interactive musical systems [1, 2]. In any case, most of these abstractions almost invariably lead to lattice structures similar to the Tonnetz [3], with perhaps the exception of Shepard's [4] and Chew's [5] helicoidal models, that attempt to bring closer the pitch-class, chordal and key domains.

Recently, Bergstrom et al. [6] developed a system (*isochords*) that visualises chord progressions and voicings at playback time, resembling an animated Tonnetz. Other efforts towards visual analysis of tonal structure are mostly grounded in the works of Sapp [7, 8], evolving into interesting analysis methods using Self Organising Maps [9, 10] and simultaneously addressing multiple temporal scales [11]. However, these representational tools are developed with the analyst in mind, rather than the music creative, and cannot be used in real time.

2.2 Measuring Harmonic Properties

Most of the representational methods we just outlined were created to give account of certain tonal properties, be these in the realms of purely music-theoretical concepts, like the Tonnetz or the Spiral Array [5], or in the context of music cognition, attempting to illuminate the ways in which we humans listen to music [3, 4, 12]. It is in this area where a number of measures of perceptual distance have arisen, such as Lerdahl's distance indicator between chords in the context of multiple musical keys [3]. Recently, Bernardes et al. [13] introduced a novel measurement that estimates the perceptual proximity and consonance of note aggregates based on a 12-dimensional Tonal Interval Space, and which they use in their own generative system.

In the domain of harmonic consonance, Parncutt, has devoted a monograph to the study of the perceptual consonance of chords and sequences [14], after the pioneering works of Terhardt [15, 16]. However, this line of work is inevitably connected to the study of timbre and psychoacoustics, and lays slightly off our discussion.

In the field of music theory, Temperley [17] suggested different operations to measure various tonal properties of pitch-class sets (henceforth pc-sets). Grounded on Euro-classical [1] music theory and corpus analysis, he designed a Bayesian framework to measure the *tonal implication* (the key that a given pc-set implies), *tonal ambiguity* (a measure of the ambiguity of a pc-set to suggest one or several keys) and *tonalness* (the degree to which a pc-set is characteristic of the style he is studying) of pc-sets.

2.3 Interacting with Harmony

Several systems have been proposed to create, modify and more generally interact with harmonic spaces in digital environments, be these chord progressions or scales. A pioneering work in the field, Levitt's *Harmony Grid* (1986), lets the user hover with the mouse over different pitch space representations, sounding individual notes or various chord types (depending on the mode of operation) in response [1]. Soon after, Holland developed a number of educational programs about harmony in which the user could play simple chord progressions by tracing lines with a mouse over a Longuet-Higgins relational space [2]. Bernardes et al. [13] recently proposed a generative harmonic model based on a set of parameters (chord vocabulary, consonance factor and distance) selected by the user.

In the realm of bodily interaction, Gatzsche et al. [19] developed a system to physically interact with tonal spaces with hardware controllers, inspired in Chew's Spiral Array [5]. Similarly, Adeney came up with a multimedia environment in which a performer can literally step over different chord symbols projected on the floor as a two-dimensional grid, creating progressions based on tonal functional harmony as the performer moves [20]. Figure 2 shows screenshots of the Graphical User Interfaces (GUI's) of the systems we just mentioned.

[1] We take this term from Tagg [18] to refer to European Classical Music of the so-called common practice repertoire, on which most treatises on harmony are based.

3. THE HOUSE HARMONIC FILLER

In this section, we describe our tentative model for interacting with chord progressions in real time. We provide it as an open source program, written in Pure Data [2] and available online. [3] The program reads chord sequences from MIDI files, analyses their harmonic content and promotes simple variations like changing the voicing, register, inversion and rhythm of the sequences, generating MIDI data that can be sent out to any chosen device or DAW.

We refer to the prototype we are describing as the *House Harmonic Filler*, inspired by Moore's nomenclature [21]. According to Moore, popular music styles can be differentiated and characterized by observing four basic textural functional layers, namely the explicit beat layer, the functional bass layer, the melodic layer and the harmonic filler layer.

3.1 Rationale

We are interested in assistive tools for creating electronic popular music based on corpus analysis. We believe this approach can help us overcome certain musical assumptions that might not apply to the modes of musical production under consideration (cfr. [22, 23] for a description of tonal properties of EDM), and help the novice or amateur electronic music producer to become familiar with the main features of a given style of music. Furthermore, statistical music analysis can be useful for the musicologist in the task of observing and formalising new operational principles.

Despite harmony not being a prominent aspect of many electronic popular music genres, it is still prevalent in those evolving directly from a song tradition, such as electro-pop and disco variants. Our choice to develop this research on a corpus of house music, is based on the following premises:

- House music is composed and performed mainly with digital technology.
- Its basic structural unit is the *loop*, normally a 2, 4 or 8-bar circularly repeating sequence that is usually layered together with other such loops, what creates clear harmonic units without cadential points.
- House music, especially so-called *deep house*, is usually composed with chord loops borrowed from styles such as soul, rhythm-and-blues or even jazz, using extended chords other than simple triads, what makes it interesting in purely harmonic terms.
- Regarding instrumentation, deep house tracks often present acoustic instruments, such as pianos, vibraphones as well as an extensive use of vocals, what would eventually let us compare the output of our system with corpora of other popular music styles.

[2] `http://puredata.info/`

[3] `www.github.com/giantSteps/house-harmonic-filler`

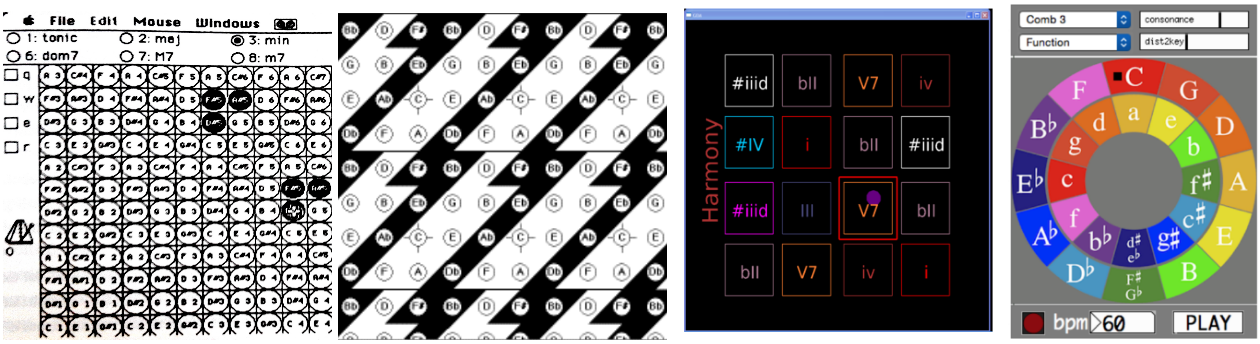

Figure 2. Graphical User Interfaces of various interactive applications dealing with harmony. From left to right: Levitt's *Harmony Grid* [1], Holland's *Harmony Space* [2], Adeney's *HarmonyGrid* [20], and Bernardes's *Conchord* [13].

3.2 Chord Shuttles and Loops

House harmonic loops normally consist of sequences of 2 or 4 bars, with a tendency to have a single chord per measure. However, 8-bar loops are less frequent, and in most cases, they result from a repetition of a 4-bar pattern with a small variation toward the end of the second half.

Currently, the House Harmonic Filler operates with two-bar shuttles and four-bar loops. According to Tagg [18], a chord shuttle consists in an ongoing oscillation between two chords, normally of equal duration and importance, what most of the times makes difficult –if useful at all– to determine which chord is the tonic in a traditional sense, effect which is enforced by the endless looping mechanism. In fact, the tonic feel in loop-based music is mostly determined by non-tonal compositional aspects, specially the explicit beat layer and the functional bass layer mentioned above, as well as the structural arrangement of loops, which results in timbral and density changes at regular hypermetric intervals [24, 25].

Moore [26] has studied the relation of specific chord progressions and different musical genres, attempting to identify specific styles (pop, rock and soul) based on a number of harmonic patterns. We consider this a potentially fruitful approach at differentiating specific electronic popular music sub-genres.

For the current study, we have used limited resources publicly available on the internet. We have gathered a collection of MIDI files containing homophonic chord loops under tags of *deep house piano*,[4] *classic house piano*[5] and *deep house chords*,[6] obtaining a total of 48 loops which we considered sufficient to study the visualization and interaction aspects that we are presenting.

3.3 General Operation

When we load a corpus of MIDI loops in the program, the system detects the number of chords in each file, their type, inversion and position in the 4-bar structure. The estimation of chord types is achieved via a lookup procedure against intervalic patterns stored in a dictionary. Once the chord sequence is determined, the system finds the root of the first chord in the loop, and establishes it as the tonic. We proceed in this fashion supported by the evidence that in short and cyclical chord progressions –as the ones described here,– the most natural presumption of a tonal centre lays on the first chord [24], especially if, as we cited above, this is emphasised by non-tonal features, such as density and timbral changes on a strict hypermetrical regularity. This hypothesis is also supported by Tagg [18]. After the analysis, the chord sequences are transposed to pitch-class 0 (C), so that users can select the key of the progression disregarding the original key.

All files in the corpus are analysed separately in terms of harmony and rhythm. This way, users can combine all rhythmic patterns in the corpus with the available chord sequences. Any chosen loop is presented in a simple display (Figure 3), showing the original rhythmic pattern in light-gray and the chord progression in Roman numeral notation. In the current version, user manipulations are limited to changes in register, spread and inversion, as well as the selection of key and some rhythmic transformations. Overall, the interface provides the following parameter controls:

- The *pattern* slider allows the user to select among existing rhythmic patterns, ordered by density and syncopation complexity.
- A *density* control changes the number of events in the loop according to an agnostic density transformer [27], allowing to create rhythmic deviations from the original pattern, presented in dark-gray in the interface (Figure 3).
- The *legato* parameter sets the relative duration of the events. Setting it to its maximum will make chords last until the next attack.
- The *octave* fader transposes the chord progression up or down.
- The *spread* slider controls the openness or closeness degree of chords, i.e., their spread over different octaves,
- while the *register* control affects their inversion type, folding chords upwards or downwards.

[4] www.loopmasters.com/genres/50-Deep-House/products/3829-Deep-House-Piano
[5] www.loopmasters.com/products/461-Classic-House-Pianos
[6] deep-house-chords.com/

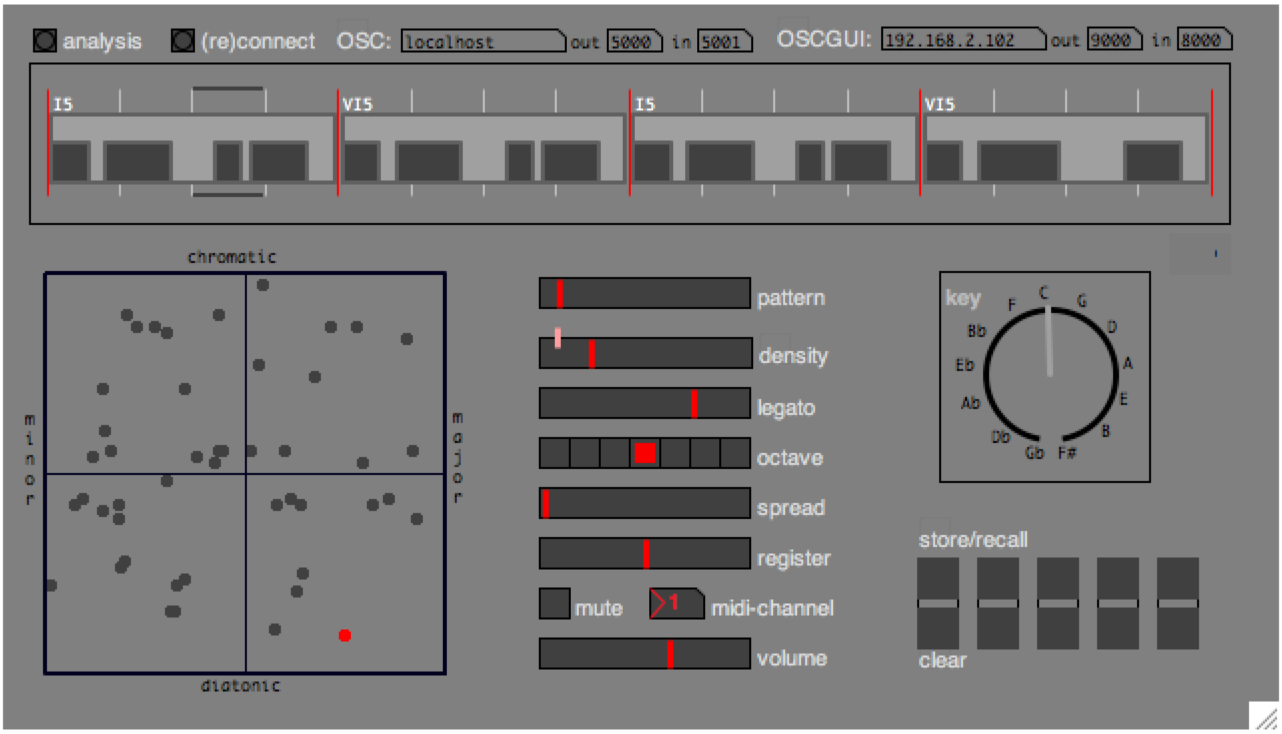

Figure 3. Graphical user interface of the House Harmonic Filler. It is composed of a chord progression selector (left), a simple visualisation of the chord sequence (top), and a few other controls to manipulate the sequence in real time.

- The *key* dial sets the key (tonic) of the progression. As we will explain in the next subsection, this is the pitch-class of the root of the first chord in the sequence. As the user might have observed in the GUI, the key control does not imply any specific modality. This is indeed only implied by the chord progression selected in the 2D space.

- Last, we provide a number of *memory slots*, so that users can store and recall between different states of the system, as well as regular *mute*, *midi channel* and *volume* controls to adjust the output parameters of the program.

3.4 The Harmony Map

3.4.1 Harmonic Analysis

Previous versions of the House Harmonic Filler had a one-dimensional drop-down menu, in which all harmonic progressions available were listed –after analysis,– in *chromatic* Roman numeral notation. All scale degrees are therefore expressed as chromatic intervals with the tonic. Figure 4 shows an example of a few such entries among which the user would need to choose:

`|I |♭VIImaj7 |Im9 |IIm9 |`

`|I9 |♭VIImaj9 |Vm11 |♭IIm9 |`

`|Im |VIIm7 |VIm7 |Vmaj7 |`

Figure 4. List of several chord progressions from our corpus of deep house loops.

A flat (♭) preceding a Roman numeral indicates a minor or diminished interval, and a lower case `m` after represents a minor chord; all non-flattened intervals refer to major or perfect intervals. This way, we intend to overcome the limitations of a mutually exclusive binary modal system, in which Roman numerals represent diatonic degrees of the scale. For example, in diatonic notation, `III` refers to the minor triad located one major third (3M) above a **major** tonic (`I`); and to the major triad one minor third (3m) above on a **minor** mode (`Im`). In chromatic notation, degrees refer unequivocally to a tonic, independently of the modality of the excerpt. Let us consider the following sequence:

`|Im9 |IIIm7 |V7 |♭VII7 |`

Reading this sequence in chromatic Roman numeral notation, if we assume, for example, `I` to be **A**, the progression results in:

`|Am9 |C♯m7 |E7 |G7 |`

The familiar reader will notice that this progression presents some mixed modality: first and last chords suggest an aeolian minor quality; however, this is broken by the second chord (which seems borrowed from the parallel key of **A major**); the third chord is ambiguous in this regard, since it belongs to both **A major** and **A minor** (harmonic).

This type of notation might be helpful to understand some harmonic features of the music under consideration, a somewhat jazzy house music. Especially, that modal variants (mixolydian, prhyrgian, etc.) are much more frequent than in common-practice harmony, and that there is a certain hybridisation of the major and minor modes. However, truth is that a regular user might be a bit disoriented when choosing a harmonic progression from a list of such entries according to her musical expectations.

3.4.2 Interactive Visualisation

In the latest version of the House Harmonic Filler we substituted the drop-down list of harmonic options with the two-dimensional interactive space shown at the left of Figure 3. In this new *harmony map*, all 4-bar chord progressions are represented as single dots in the space that users can click on to select them.

The harmony map intends to represent in a simple way some tonal properties of the chord progressions, regarding modality and tonal tension, over which the user can make herself an idea of the general tonal quality of the sequences without dealing with theoretical notations. Dots at the bottom of the graph are harmonically simpler than those at the top, whereas the horizontal axis represents a modal continuum from minor to major modes, passing through various modal variants.

In our grid, the x-axis represents, from left to right, a discrete progression of six possible modal variants, three minor and three major modes, arranged in the following order: *phrygian, aeolian, dorian, mixolydian, ionian* and *lydian*. The criterion for choosing this order was to arrange the various scalar possibilities from minor to major in the smoothest possible way, that is, keeping as many common notes as possible between nearby modes. In this setting, the typical modes of reference, *aeolian* (minor), and *ionian* (major) are located symmetrically at both sides. Figure 5 shows the modal arrangement of the x-axis indicating the changing notes between modes. To find the horizontal position of a given chord progression, we extract its pitch-class profile and calculate its euclidean distance to a set of stored templates with the modal variants, selecting the shortest interval.

The y-axis, also called the *diatonic-chromatic* axis, represents a measure of the overall tonal tension of the chord progression. We have obtained this measure by counting the number of different pitch-classes in the loop, together with the number of semitones between elements of the pc-set. This simple measure positions diatonic chordal progressions (with simple chords and diatonic notes) below, and brings the more colourful, *jazzy* or chromatic sequences to the upper part of the graph.

4. DISCUSSION

The grid in Figure 3 shows our corpus of house music distributed in the harmonic map. According to the representation, the corpus has a number of minor and major progressions (rich in modal variants), with sequences ranging from very diatonic at the bottom of the space to relatively chromatic ones. For example, the sequence corresponding to the red dot in Figure 3 corresponds to the following progression:

```
|I5 |VI5 |
```

Pr	Ae	Do	Mi	Io	Ly
b7	b7	b7	**b7** →	**7**	7
b6	**b6** →	**6**	6	6	6
5	5	5	5	5	5
4	4	4	4	**4** →	**#4**
b3	b3	**b3** →	**3**	3	3
b2 →	**2**	2	2	2	2
1	1	1	1	1	1
Pr	Ae	Do	Mi	Io	Ly

Figure 5. Modal distribution along the x-axis in the House Harmonic Filler. Degrees in red highlight interval changes across different modes.

The sequence is indeed highly diatonic. It presents a tonic chord without a third (`I5`) followed by the same type on the submediant (`VI5`). Therefore this progression has no semitones. If we translate all notes in the sequence to pitch-classes, reading the progression in **C**, we obtain the collection `[0,4,7,9]`. Although this pc-set seems clearly major (due to the presence of the tonic major chord in the set) it lacks the seventh degree –that would determine if this sequence is a ionian or mixolydian modal variant,– as well as the fourth –what would define it as ionian or lydian. Therefore, the dot is located in the middle of the major left half of the map, according to the distribution in Figure 5. This limitation to indicate the modal ambiguity of some chord progressions, is one of the main shortcomings of our system as it is.

Figure 6 shows images of the harmony map with two other small corpora. For the sake of comparison, we have created two sets of 20 MIDI files with 4-bar sequences of jazz standards (as notated in the Real Book [28]) and pop-rock songs from the Billboard dataset, respectively [29]. The only criterion to choose the sequences was that original chord progressions were repeated identically at least two times, in order to recreate the looping nature of our sequences, even if these types of music are not fundamentally based on loops. As it can be seen in Figure 6, the jazz corpus has slightly more presence in the two upper quadrants, what resonates with intuitions about jazz music being more chromatic (with chord extensions and local chromatic substitutions) that other musical styles. Alternatively, the grid representing items from the Billboard hits, clusters almost exclusively onto the lower quadrants, what again, aligns with regular intuitions about pop-rock music being mainly diatonic. Interestingly enough, a group of 5 points concentrate around the same area, exactly in the middle of the horizontal axis. That might be explained by the fact that a lot of rock music seems to be composed with very similar –if not identical– harmonic structures.

At the time of this report, we have conducted informal

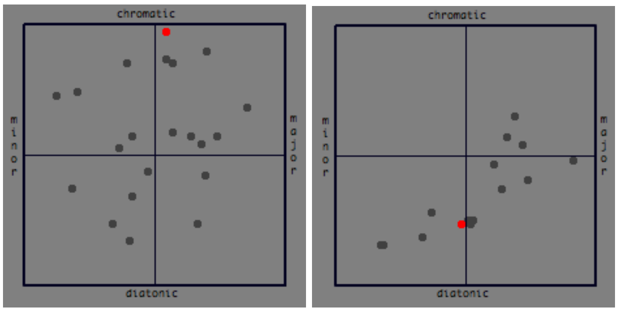

Figure 6. The two-dimensional harmony map with a small corpus of jazz progressions (left) and pop-rock music hits from the American Billboard (right).

testing with 15 subjects. All of them had some experience in music making, although only 5 of them were formally trained. In general, opinions were favourable regarding the use of the two-dimensional space. Untrained musicians regarded the axis labels to be sufficiently clear (major/minor, diatonic/chromatic), although they admitted they could not understand the Roman numeral notation in the progression display. Small frustrations arose from the limitation of the available progressions and variation strategies, one of the clear shortcomings of the program as it is now. At the moment, no chord expansion or substitution is possible, so the user is left with a few options affecting chordal voicings, plus a range of choice exclusively dependent on the preloaded corpus.

5. CONCLUSIONS AND FUTURE WORK

In this paper we presented the House Harmonic Filler, a computer program that generates house music loops and variations, with an emphasis on a two-dimensional interactive space that represents chord progressions in an intuitive way. The reduction of the chord sequences as dots was achieved with an *ad hoc* measure compressing relevant information on modality and diatonicism. However, certain modal ambiguities are not yet well represented in the map, something that we will like to address in future versions.

According to preliminary tests, this visualisation helps users unfamiliar with music theoretical notions to navigate among a closed set of possibilities. It is an endeavour for the future to design and carry on a systematic evaluation, based on user task-oriented experiments.

Similarly, we shall explore representations built over different measures, such as other types of harmonic distance (cfr. Lerdahl [3]), consonance ratios (e.g. Bernardes et al. [13]) and psychoacoustical dissimilarities, based on the measures by Parncutt [14].

We also envision an expansion of the program to allow interpolation between different chord progressions, overcoming some limitations that arise when only small corpora are available, as well as enabling a wider range of variations of the existing chord sequences. We see that an interpolation model could actually open up a space to think about chord substitutions and chordal expansions in ways that compel with the visual metaphor that we presented, as well as with musical intuitions and theoretical knowledge.

Acknowledgments

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