Interface Design for Empowerment: a Case Study from Music

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Interface design for empowerment: a case study from music

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1. Introduction

The work reported here is part of a wider project [5,6,7,8] to find ways of using artificial intelligence and education techniques to encourage and facilitate music composition by novices. The project is aimed at novices with little or no formal musical education, especially those outside a formal educational setting. For this reason, we have used illustrations and vocabulary from popular music and jazz, although the work applies equally to tonal harmony in general (see the appendix at the end of this paper for the conventions used for notating chord sequences). The research exploits two recent cognitive theories of harmony due to Longuet-Higgins [11,12] and Balzano [1] which give rise to principled and elegant representations for harmonic relationships. In this discussion we will concentrate on the use of a modified version of Longuet-Higgins' theory, although we have obtained very closely related results [6] using a version of Balzano's theory.

2. Longuet-Higgins' theory of harmony

Longuet-Higgins' theory of harmony [11,12] investigates the properties of an array of notes arranged in ascending perfect fifths on one axis and major thirds on the other axis (figure 1)[1]. Longuet-Higgins' representation turns out to be a good framework for theories explaining how people perceive and process tonal harmony [15]. Longuet-Higgins' [11,12] theory asserts that the set of intervals that occur in Western tonal music are those between notes whose frequencies are in ratios expressible as the product of the three prime factors 2, 3, and 5 and no others. Given this premise, it follows from the fundamental theorem of arithmetic that the set of three intervals consisting of the octave, the perfect fifth and the major third is the *only* co-ordinate system that can allow all intervals in musical use (and only those intervals) to be given *unique* co-ordinates. We can represent this graphically by laying out notes in a three dimensional grid with notes ascending in octaves, perfect thirds and major fifths

[1] In Longuet-Higgins' presentations of the theory, and in all discussions of it in the psychological literature, the convention is that ascending perfect fifths appear on the x-axis and the ascending major thirds on the y-axis. We reverse this for educational purposes on two grounds. Firstly, it allows students to switch more easily between the Balzano representation and the 12-note version of the Longuet-Higgins representation. (The x-axes become coincident and the y-axes are seen to be related by a 'shear' operation.) Secondly, the V-I movements that dominate Western tonal harmony at so many different levels become aligned with physical gravity in a metaphor useful to novices.

along the three axes. The octave dimension is discarded in most discussions on grounds of octave equivalence and of practical convenience for focussing on the other two dimensions (figure 1).

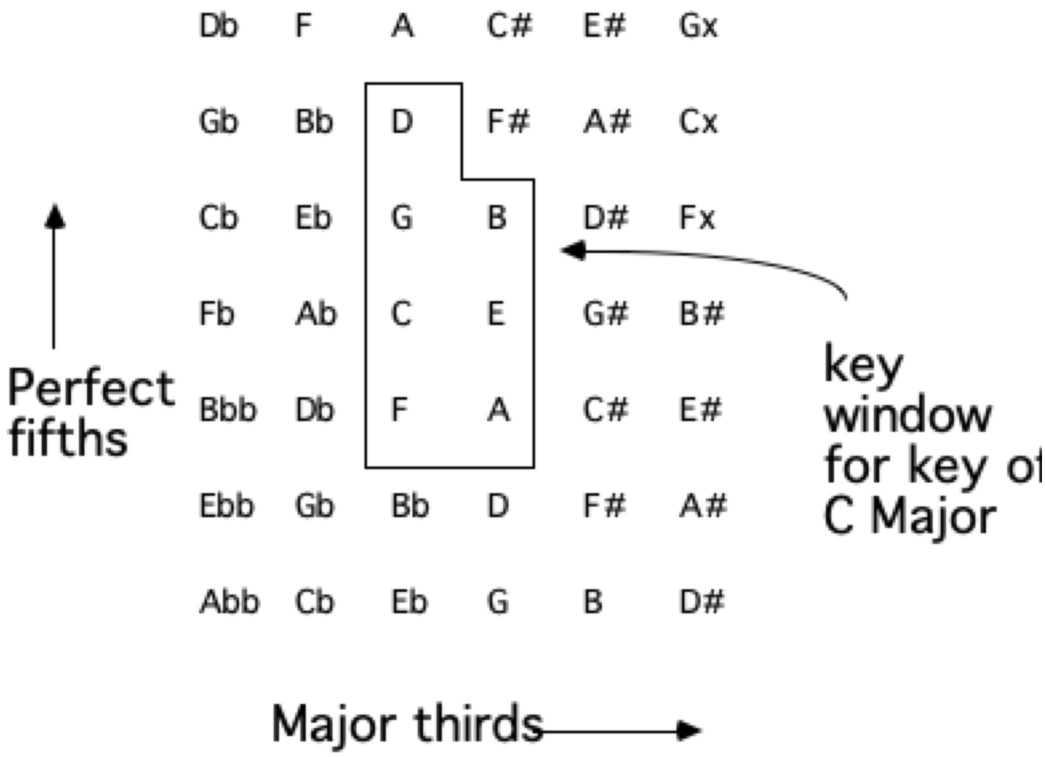


Figure 1. Longuet-Higgins' note array
Diagram adapted from Longuet-Higgins [11]

The theory has been of great interest in the cognitive psychology of music [9] as a framework for explaining how people perceive and process tonal harmony. Our chosen focus here is on applying the theory to develop new educational tools.

2.1 Keys and modulation

We begin by looking at how various 'static' relationships in harmony appear in this representation. In diagrams such as figure 1, all of the notes of the diatonic scale are 'clumped' into a compact region. For example, all of the notes of C major, and no other notes, are contained in the box or window in figure 1. If we imagine the box or window as being free to slide around over the fixed grid of notes, we will see that moving the window vertically upwards or downwards, for example, corresponds to modulation to the dominant and subdominant keys respectively. Other keys can be found by sliding the window in other directions. Despite the repetition of note names, it is important to realise that notes with the same name in different positions are not the same note, but notes with the same name in different key relationships.
However, for the purposes of educating novices in the elementary facts of tonal harmony it turns out to be convenient to map Longuet-Higgins' space onto the twelve note vocabulary of a fixed-tuning instrument, resulting in a 12-note, two-dimensional version of Longuet-Higgins' space. The collapse to the 12-fold space makes it apparently impossible to make distinctions about note spelling that could be made in the original space. However, we can console ourselves with the thought than in this respect it is no more misleading than a piano keyboard. (And we will see shortly that it makes many harmonic relationships far clearer than a piano keyboard does.)
As a result of our decision, the double sharps and double flats of figure 1 are lost, and

the space now repeats exactly in all directions (figure 2). Notes with the same name really are the same note in this space. In fact a little thought will show that the space is in fact a torus, which we have unfolded and repeated like a wallpaper pattern. Instead of a single key window there are replicated copies of the same key window.

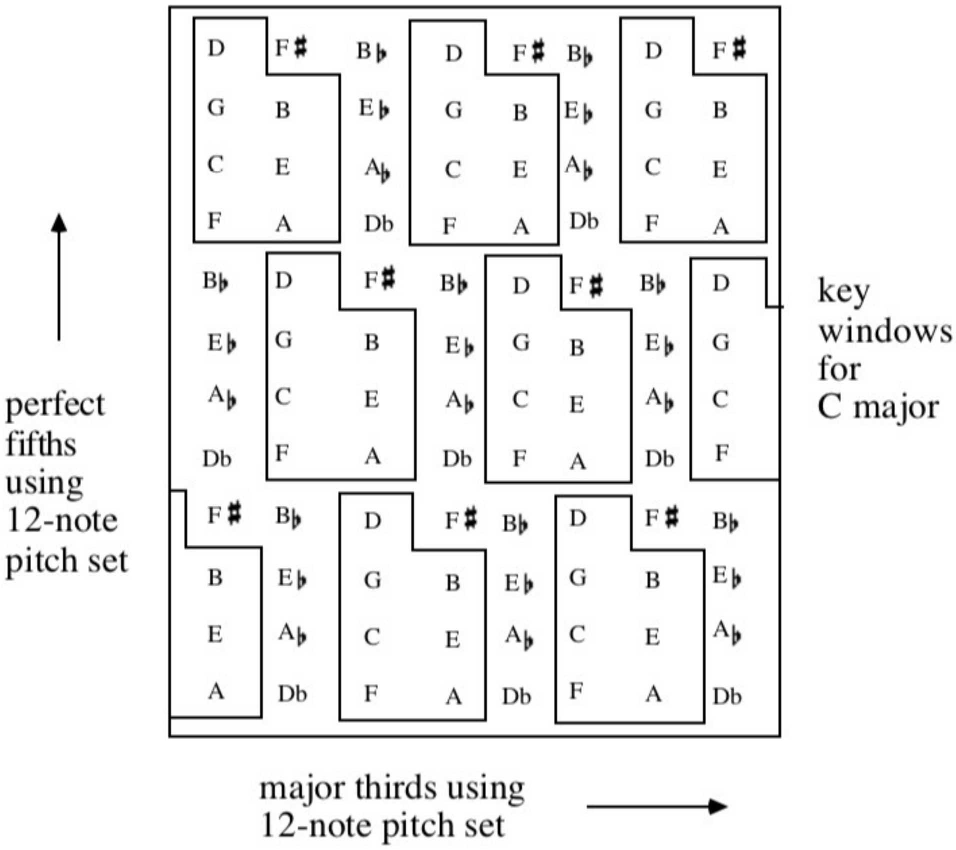
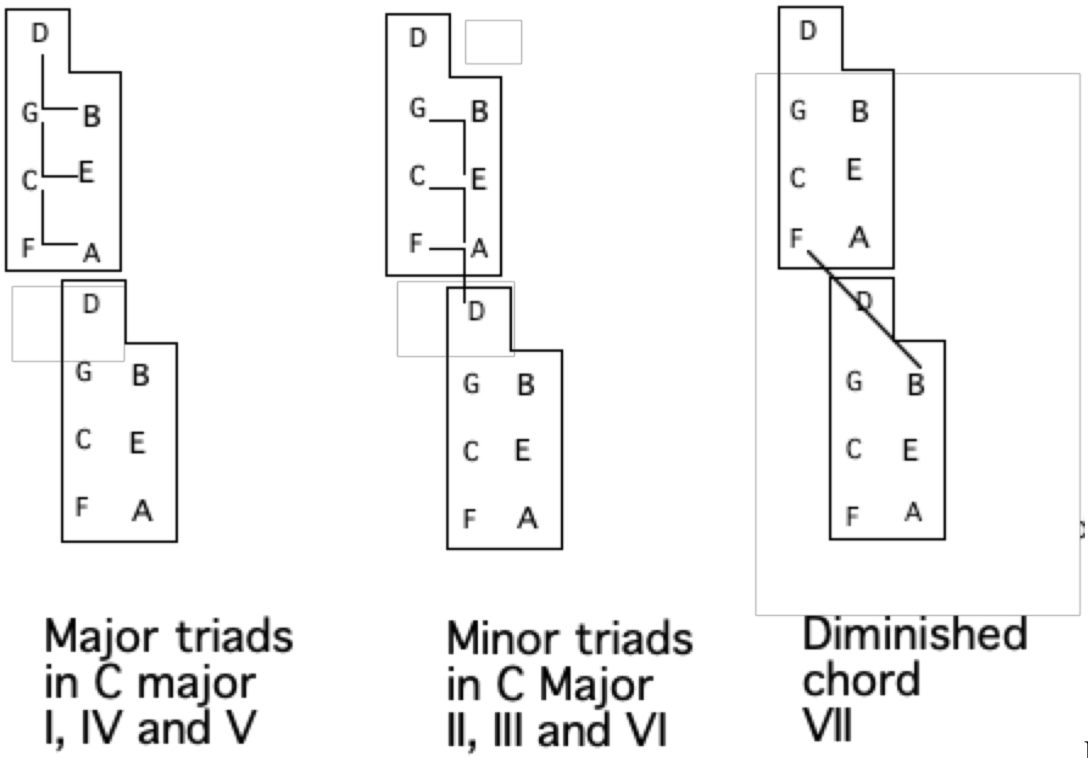


Figure 2. 12-note version of Longuet-Higgins' note array

Note that we have used arbitrary spellings in these diagrams (e.g.. F# instead of Gb etc.), but we could equally easily use neutral semitone numbers or some other preferred convention.

2.2 Chords and tonal centres

Let us now turn to look at the representation of triads and tonal centres. In 12-note versions of Longuet-Higgins' space, major triads correspond to L-shapes (figure 3). A triad consists of three maximally close distinct notes in a configuration that can fit a key window. The dominant and subdominant triads are maximally close to the tonic triad. We can see from the diagram that the three primary triads contain all the notes in the diatonic scale. Notice also that we have a clear spatial metaphor for the centrality of the tonic - the tonic triad is literally the central one of the three major triads of any major key. We can make similar observations for the minor triads. Minor triads correspond to rotated L-shapes. Like major triads, they are maximally compact three-element objects that can fit a key window. The three secondary triads generate the natural minor (and major) scale (We can deal with harmonic and melodic minor scales by introducing variant key window shapes, but we will not pursue this here). Also, the space gives a clear visual metaphor for the centrality of the relative minor triad among the secondary triads[2]. Completing the full set of scale tone triads for the major scale, the diminished triad is a sloping straight line. Seventh or ninth chords similarly have memorable and consistent shapes in the 12-note space. See figure 4 for the representation of scale tone sevenths.



F
igure 3 Triads in the 12-fold space

3 A computer-based interface

We will now present the essential points of the design of an interface, Harmony Space, based on the Longuet-Higgins' representation. Several versions of the interface have been implemented that exhibit in various form all of the key design decisions described below. There is a grid of notes displayed on a computer screen, each circle representing a note. Two pointing devices, such as mice, are provided. One mouse controls the location of a cursor that highlights and sounds any note-circle it passes over, provided the mouse button is down at the time. More generally, the mouse can control the location of the root of a diad, triad, seventh or ninth chord. (We will refer to the number of notes in the chord as its 'chord-size'.) The chord-size can be varied by the user using a second pointing device or control keys. As the root is moved around, the quality of the chord automatically changes appropriately for the position of the root in the scale. So for example, unless overridden with the other mouse by

[2] The 'centrality of the tonic' argument as applied to the tonal centre of the minor mode is borrowed from Balzano [1]. It is not valid in the full non-repeating Longuet-Higgins space but works in the 12-note Longuet-Higgins version.

the user, the chord on the tonic will be a major triad (or major seventh if we are using sevenths) and the chord on the supertonic will be a minor triad (or minor seventh if we are using sevenths). We refer to these chord qualities as the *default* chord qualities for the chord-size and degree of the scale. Of course, default chord qualities will sometimes need to be overridden. As we have already mentioned in passing, this is controlled using a second pointing device (control keys are used in all versions implemented to date).

Although the qualities of chords are assigned automatically by default as the root is moved by the user, there is a clear visual metaphor for the basis of the automatic choice, because *the shape of the chord appears to change to fit the physical constraint of the key window*. The second pointing device is also used to move the key window. Moving this pointing device corresponds to changing key. If, for example we modulate by moving the window while sounding the same chord root, the chord quality may change. Once again there is a clear visual metaphor for what is happening since the shape of the chord will appear to be "squeezed" to fit the new position of the key window. Note circles can be displayed with alphabetical pitch names (e.g. C, G, Eb, etc.) or functional names (e.g. I, V, IIIb, etc.). The alphabetical pitch name associated with a given note circle remains fixed irrespective of the position of the key window, whereas the functional name associated with a note circle varies as the key window is moved, in accordance with the meaning of functional names.

The interface is linked to a synthesizer so that everything we have described can be heard at the same time. The resulting interface of which we have given an outline description is called "Harmony Space".

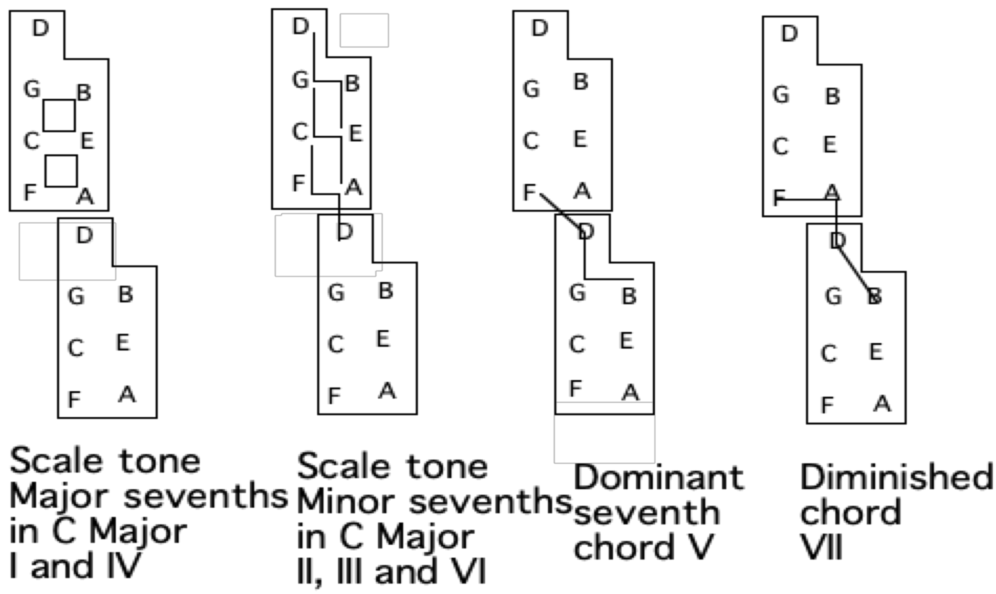


Figure 4. Scale tone seventh chords in 12-fold space

3.1 Representing harmonic progression

So far we have looked at the representation of key areas and chords in the 12-fold space. Let us now move on to look at harmonic progression and succession. It turns out that many of the fundamental harmonic progressions of Western tonal music correspond to very simple paths in Harmony Space. These patterns do not appear to have been noted explicitly in previous discussions of Longuet-Higgins' or Balzano's theories, perhaps because Longuet-Higgins' theory is usually considered in the *non-repeating* form where these patterns do not appear, and Balzano's theory is usually applied to quite different purposes.

Firstly, the I V I progression which is so commonplace in tonal music can be seen as one that begins on the central major triad of the key, and then moves to a maximally close neighbour before returning home (figure 3). Similarly, progressions involving I, IV and V can be seen as oscillating either side of the tonal centre by the smallest possible step and then returning home.

Moving onto wider chord vocabularies, we notice that fundamental progressions like II V I, VI II V I , III VI II V I etc. (see the appendix for the chord notation convention) correspond to straight lines vertically downward in the 12-fold space with a tonal centre as their target (figure 5). We refer to straight line motions in 12-fold Harmony Space to tonal goals as ***harmonic trajectories.***

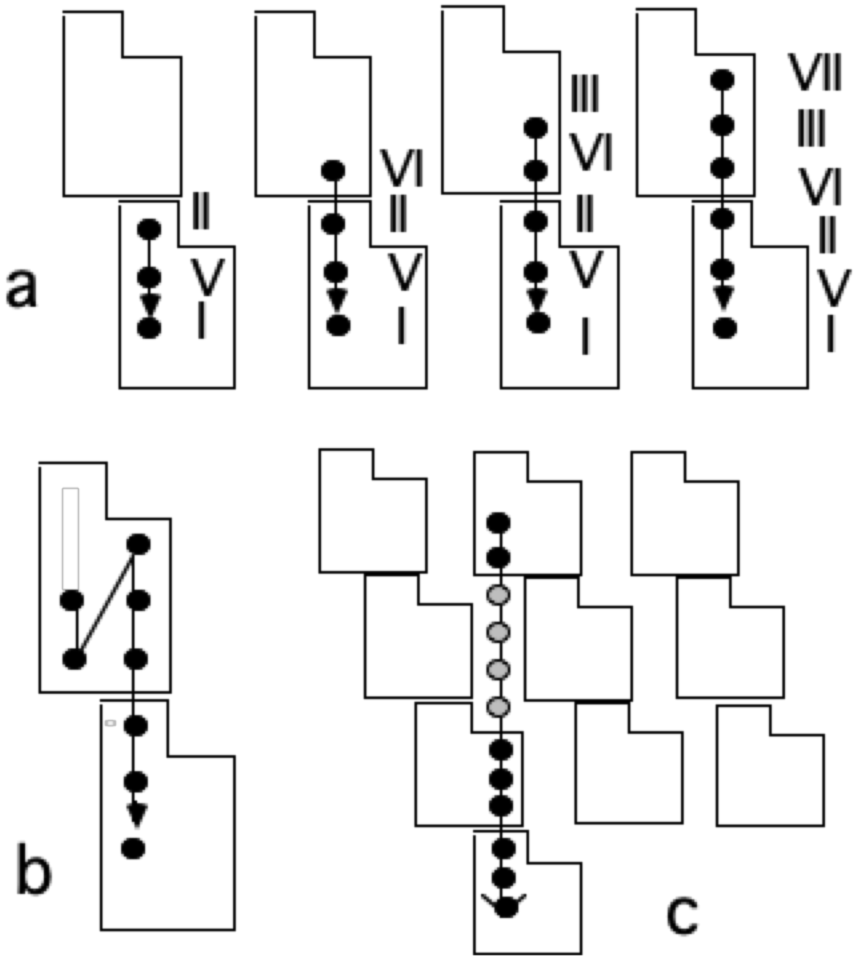


Figure 5. Circles of fifths in 12-fold space

The circle of fifths is of fundamental importance in western tonal music. We can distinguish between two classes of circle of fifths. In the first case, 'real' circle of fifths, the root moves in straight lines down the perfect fifth axis, sounding all roots on its path, irrespective of whether they are inside or outside the key window - e.g. figure 5c (including half-shaded points). In the second case (tonal circle of fifths) *only notes in the key window are sounded.* In Harmony Space this corresponds to straight lines that "jump" where necessary to avoid notes outside the key window - e.g. figure 5c *excluding* half-shaded points. For example, if we are in the key of C, the root is forced to make an irregular jump of a diminished fifth from F to B in order to stay in key. Note that the "jumps" can be drawn equivalently as "bends" (e.g. figure 5b) due to the fact that different occurrences of notes with the same name in the space are equivalent notes.

Using the interface, we can audibly and visibly play tonal circles of fifths simply by making a vertical straight line gesture with the mouse. The chord quality can be seen and heard flexing to fit within the key window (figures 3 and 4). This works even if there are modulations (movements of the key window) mid-chord sequence. To play a real circle of fifths, we simply switch off the option that prevents us sounding roots in the chromatic area outside the key window. (Note that for chords with roots outside the key window, there are no "obvious" chord qualities. Such chords may be assigned some arbitrary quality in advance or may be given an appropriate quality by hand with the second pointing device as they occur.)

3.2 Manipulating and representing arbitrary harmonic sequences

In general, it turns out that straight line gestures on various axes in Harmony Space, particularly gestures ending on tonal centres, are of particular importance or interest in Western tonal harmony. The circle of fifths progressions already seen are in many ways the most important. Some related progressions are discussed below.

If we reverse the direction of movement on the circle of fifths axis and consider chord sequences moving vertically upwards, we have what might be called, following Steedman [18], *extended plagal sequences* and cadences. Short plagal cadences are very common but extended chord sequences of this sort (i.e. chord sequences like I V II VI etc.) are rare, probably for reasons explored by Steedman [18]. Extended plagal chord sequences are occasionally used as the basis for short pieces, for example "Hey Joe" (popular arr. Jimi Hendrix).

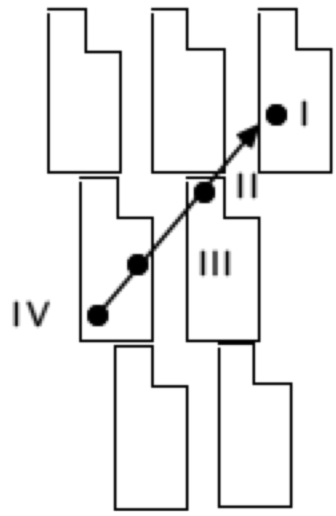


Figure 6. Scalic progressions

Turning to other axes of Harmony Space, scalic sequences (i.e. we use this term to mean movement up and down the diatonic scale) can be represented as *diagonal* trajectories constrained to remain within the key windows (figure 6). So for

example, the chord sequences I II III II I,   IV III II I etc. can be represented as diagonal trajectories or diagonal oscillations. Scalic root movement is frequent in tonal music in short sequences and is often used as the basis of harmonic sequences in modal music, for example, commonly by Michael Jackson and Phil Collins.
If the constraint is removed that the root must stay within the key window, scalic sequences become chromatic sequences (figure 7). Chromatic chord succession is widely used in some jazz dialects. Such chord progressions coincide on every other chord with a circle of fifths progression, and are viewed in some circumstances by jazz musicians as substitutes for circles of fifths (in a jazz practice known as "tritone substitution").
Extended straight line harmonic trajectories in 'real' (chromatic) major or minor thirds are not harmonically very useful because they touch few roots in any given key. Diatonic progressions in thirds,where the roots move through alternating intervals of major and minor thirds, are sometimes used as a basis for pieces and can be played easily in Harmony Space with a zig-zagging gesture.
In summary, simple extended physical gestures such as straight lines along appropriate axes towards tonal centres correspond to important harmonic progressions in tonal harmony. Other basic progressions correspond to further simple patterns (not explored here). In general, we can play any desired chord sequences in Harmony Space by making gestures in the appropriate directions.
It is important to note that a visual formalism is not being proposed as a substitute for listening. However, Harmony Space can allow novices without instrumental skills and without knowledge of standard theory or terminology to gain experience of controlling and analysing such sequences. Harmony Space is also a good place to learn music theory if a novice so desires.

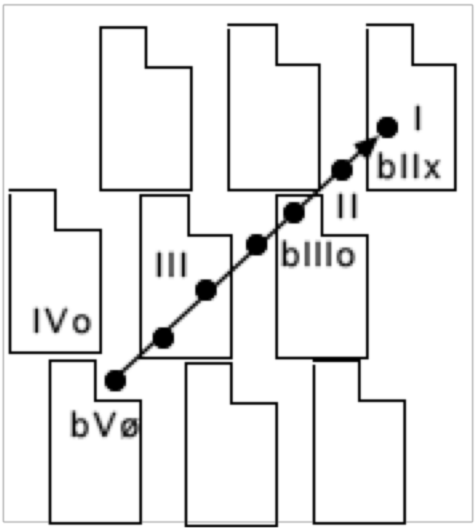


Figure 7 Chromatic progressions

4 Informal qualitative investigation

An informal qualitative investigation was carried out with a small number subjects to discover whether Harmony Space is usable by novices and to find out whether it can enable them to perform musical tasks that would normally be difficult for novices to carry out by other means. We summarise briefly the results of this investigation. Full details can be found in Holland [6]. In brief, it was demonstrated that musical novices with no previous musical training can be taught, using Harmony Space, in

the space of between 10 minutes and two and a half hours to carry out tasks including:
• Perform harmonic analyses of the chord functions and modulations (ignoring inversions) of such pieces as Mozart's "Ave Verum Corpus". The harmonic analysis was performed on a version played in triads, in close position, in root inversion. This task was carried out by one subject after only 10 minutes training.
• Accompany sung performances of songs, playing the correct chords, on the basis of simple verbal instructions or demonstrations. Songs were selected with a range of contrasting harmonic constructions.
• Learn and perform simple strategies for composing chord sequences using 'musical plans' such as 'return home', 'cautious exploration', 'moving goal-post' and 'modal harmonic ostinato'. More details of 'musical plans' can be found in Holland [5,6].
• Modify existing chord sequences in musically 'sensible' ways, for example perform what jazz musicians refer to as 'tritone substitutions' on simple jazz chord sequences.
• Play and recognise various classes of abstractly described, musically useful chord sequences in various keys both diatonically and chromatically.
• Carry out various musical tasks, such as to recognise and distinguish chord qualities; to use the rule for scale tone chord construction; to locate major and minor tonic degrees in any key; and to make use of the rationale for the centrality of the major and minor tonics.
• Locate, recognise and distinguish examples of important harmonic entities and phenomena. For example: identify examples of the major and minor tonics, modulations, and major and minor triads in various keys.

We will summarise the most important limitations of the investigation. It was a qualitative evaluation. The sample was small (five subjects), though of varied age, nationality and social background. Only single sessions were used. The harmonic analyses were performed on reduced harmonic versions played in triads, in close position, in root inversion. Given these limitations, the investigation indicated that beginners with no previous musical training and a wide range of ages can be taught very quickly to use the interface. It was demonstrated that musical novices can be taught in a matter of minutes using the prototype to carry out a range of musical tasks that it would typically take weeks or months for beginners to learn by conventional methods.

5 Related work

To the best of our knowledge, the work described in this chapter was the first application of Longuet-Higgins' theory for educational purposes. Holland [8] appears to be the first discussion of use of Longuet-Higgins' representation for controlling a musical instrument, and the implemented prototype appears to be the first such instrument constructed. A number of musical interfaces, each related in some way to Harmony Space are described below. Each was developed independently of the others. The first device is Longuet-Higgins' light organLonguet-Higgins (reported in Steedman [17] page 127) connected each key of an electronic organ to an square array of light bulbs illuminating note names. This device was the first instrument to make explicit use of Longuet-Higgins' theory. It allowed music played on the organ to be displayed in Longuet-Higgins' non-repeating space. However, the question did not arise of working in the opposite direction to allow the grid representation to control the organ. The use of the non-repeating space means that the paths we have discussed do not emerge as straight lines. The key window does not appear to have been represented on the display.

The first computer-controlled device using a generalised two-dimensional note-array (the meaning of this should become clear in a moment) with pointing device to control a musical instrument seems to be Levitt's program Harmony Grid (figure 8) [10]. Harmony Grid runs on an Apple Macintosh. It displays a two dimensional grid of notes where the interval between adjacent notes may be adjusted independently for the x and y axes to any arbitrary number of semitone steps. The grid display can control or display the output of any musical instrument with a MIDI interface (Musical Instrument Digital Interface - an industry interconnection standard). Harmony Grid can be configured as a special case to the grid layouts of Balzano's space or Longuet-Higgins 12-fold space. However, the question of key windows, or their analogue, is not considered in Harmony Grid. This means that Harmony Grid does not make explicit the bulk of the relationships and structures described in this chapter. The mouse can control chords, but their quality must be adjusted manually - there is no notion of inheriting or constraining chord quality from a key window. Hence modulation can be carried out only by knowing and manually selecting the appropriate chord quality as each chord is played. Levitt's pioneering program is a superb educational tool, robustly implemented with a good real time response and many practical features. It was the first implemented program of its kind. The many differences and similarities between Harmony Space and Harmony Grid raise very interesting musical, educational and interface design issues, but they are beyond the scope of this chapter.

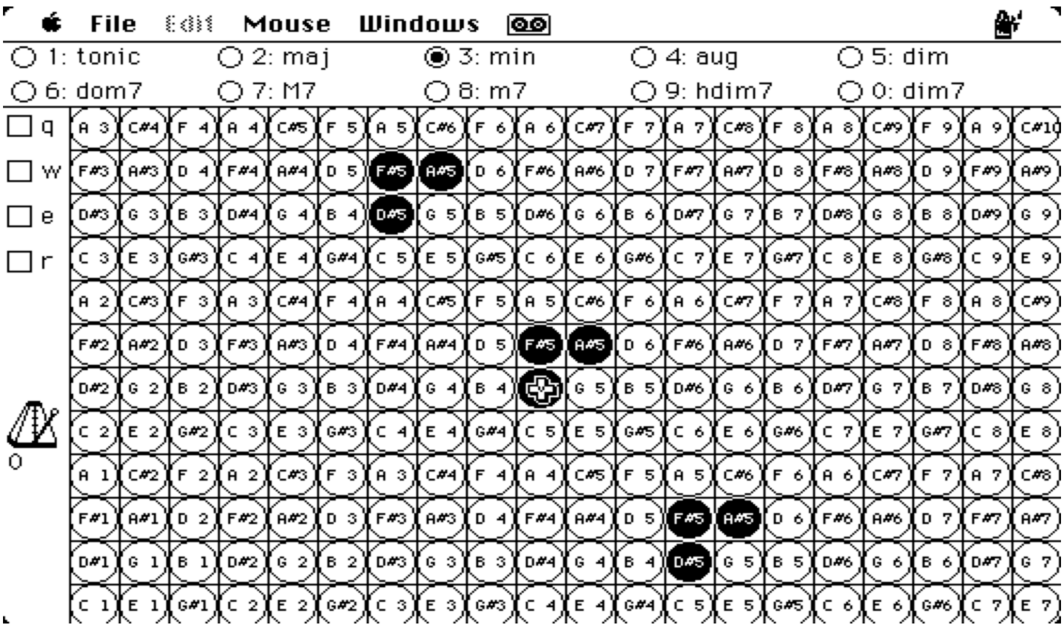


Figure 8 Harmony Grid

Balzano has worked on the design of computer-based educational tools for learning about music. At a conference, Balzano [2] referred to an educational tool based on his group-theoretic approach to harmony, but this does not appear to have been discussed in the literature yet.

6 Recent developments and limitations

The original implementations of Harmony Space (1986) were experimental prototypes designed to show the coherence and practicality of the design. The prototypes served their intended purpose, but were too slow and basic to make them easy to use.

More recently, much more sophisticated and general versions of Harmony Space have been implemented on SPARC workstations working with James Bisset and Colin Watson. These versions are very accurate and fast, and the latest version is switchable between many configurations including the Balzano and Longuet-Higgins spaces, as well as several theoretically interesting microtonal spaces. It can be linked to a variety of rhythmical filters, and is a "two and a half dimensional" interface, making use of shading to show information about octaves and inversion. This version has facilities for recording performances, and being driven by a guided discovery intelligent tutoring system for music composition [6]. A performance event using a specially constructed human-powered version of Harmony Space was performed at the Utrecht Art School's Centre for Knowledge Technology at the invitation of Peter Design and Henkjan Honing in 1990. Part of the aim was to allow people to experience and control harmony and melody with the movement of their whole bodies. In a series of games, participants moved around in a large Harmony Space grid marked out on the floor. Their movements 'controlled' a specially trained group of musicians whose playing was partly determined by the Harmony Space configuration. A large, specially constructed wooden key window was shifted around under the players' feet to control modulations. Games included 'exploratory walks', polyphonic games, improvisatory games and discovery learning games.

A straightforward extension of the present research would be a systematic educational evaluation of Harmony Space. One simple empirical investigation planned is to take a small group of students and find out the extent to which composition, analysis, accompaniment and music theory skills learned using harmony space can be transferred to keyboards.

There are some aspects of harmony that Harmony Space does not represent well, for example, voice-leading, the control and representation of voicing and inversion, and the visualisation and control of harmony in a metrical context. Harmony Space emphasises vertical aspects (in the traditional musical sense) at the expense of linear aspects of harmony. To a large extent this is an inherent limitation of Harmony Space, although Harmony Space can demonstrate some special cases of voice leading rather well [8]. Some other limitations of the research are as follows: Harmony Space deals only with tonal harmony; Harmony Space is not very well suited to dealing with melody and rhythm; inverted harmonic functions have been ignored, some musical terms and notations have been used in unusual ways. Details of possible ways of addressing some of these problems can be found in Holland [6].

7 Harmony Space and interface design

Harmony Space exemplifies and combines a high density of generally applicable interface techniques for making abstract or inaccessible entities and relationships accessible. Theories of interface design are scarce, but it is suggested that Harmony Space may provide a useful precedent for future research on interfaces designed to promote accessibility. Four techniques simultaneously exemplified by Harmony Space can be identified as follows;

• Make visible a representation underlying a theory of the domain. In the case of Harmony Space, Longuet-Higgins' 12-fold space (and the structures implicit in it) are made concretely visible and directly manipulable. In TPM (the Transparent Prolog Machine, Eisenstadt and Brayshaw [4], the proof trees underlying Prolog execution are made dynamically visible (but not directly manipulable).

• Map a task analogically from a sensory modality in which a task is difficult or impossible for some class of user into another modality where it is easy or at least possible to perform. Apart from Harmony Space, other interfaces that use this technique include Edward’s Soundtrack [3], Harmony Grid and Eisenstadt and

Brayshaw's TPM [4]. Soundtrack maps a WIMP graphic interface into the auditory modality so that blind and partially sighted users can use it.
• Use a single, uniform, principled metaphor to render abstract, theoretical relationships into a form that can be concretely experienced and experimented with. In the case of Harmony Space, the abstractions are those of music theory. A striking recent example of another interface using this technique is ARK (the Alternative Reality Kit), due to Smith [16]. In ARK, all objects represented in the interface have position, velocity and mass and can be manipulated and 'thrown' with a mouse-driven 'hand'. The laws of motion and gravity are enforced but may be modified, allowing students to perform alternative universe experiments. Much of the experiences it deals with cannot normally otherwise be experienced in the original modality and must normally be approached using abstract formulae. ARK uses the abstractions of physics to create a world in which such local barriers can be surmounted, allowing students access to normally inaccessible experiences.
• Search for and exploit a single metaphor that allows principles of consistency, simplicity, reduction of short term memory load and exploitation of existing knowledge to be used. The aim is to make a task normally difficult for novices easy to to perform. Harmony Space does this (this is analysed in detail in Holland [6]), but perhaps the best known example of such an interface is the Xerox Star (and latterly Macintosh) interfaces, which exploit a shared office metaphor and uniform commands consistently across a range of contexts.
None of these techniques is new by itself. However, just as the notion of 'direct manipulation' (Shneiderman, [14]) characterised existing practices in a useful way, it may be that new combinations of practices are starting to emerge whose identification and analysis would be of general value in designing interfaces to promote accessibility. An interesting research program would be to analyse these and other highly empowering interfaces, with the aim of explicitly characterising and generalising the techniques they use, and establishing the extent to which they can be applied to wider domains.

8 Conclusions

We have presented a theoretically motivated design for a computer-based interface for exploring tonal harmony. The interface exploits cognitive theories to give principled, uniform, metaphors in two sensory modalities (visual and kinaesthetic) for harmonic relationships and processes occurring in a third modality (the auditory). Various versions of the interface have been constructed. A qualitative investigation has demonstrated that the interface can enable musical novices to learn very quickly to perform a range of tasks that would normally be very difficult for them to do.
It has been shown that many of the fundamental harmonic progressions of Western tonal music correspond to very simple paths in Harmony Space. These patterns do not appear to have been noted previously in discussions of Longuet-Higgins' or Balzano's theories, perhaps because Longuet-Higgins' theory is usually considered in the *non-repeating* form where these patterns do not appear, and Balzano's theory is usually applied to quite different purposes.
To the best of our knowledge, the work described in this chapter was the first application of Longuet-Higgins' theory for educational purposes, and the first use of Longuet-Higgins' representation for controlling a musical instrument.
We have identified a number of generally applicable interface design approaches in common to the following: Harmony Space, an interface for Prolog programming, an interface for Newtonian physics, and an auditory interfaces for blind users. It is suggested that analysis of such design approaches may contribute to general theoretical frameworks for the design of highly empowering interfaces.

Acknowledgements
Thanks to Mark Elsom-Cook. This paper would not have existed without Mark Steedman's suggestion that Longuet-Higgins' theory was a good area to explore for educational applications. Thanks to Tim O'Shea for much help. Thanks to Mark Steedman, John Sloboda, Trevor Bray, Richard Middleton, Alistair Edwards and Mike Baker for comments on earlier drafts. Thanks to Christopher Longuet-Higgins, Ed Lisle and Mike Baker for valuable discussions. Thanks to James Bisset and Colin Watson for their enthusiastic work on new implementations. The support by the ESRC of this work under doctoral research studentship C00428525025 is gratefully acknowledged.
This paper incorporates edited, supplemented, and revised versions of some material that appeared as part of an article in the proceedings of the 1987 International Computer Music Conference as Holland [7].

Appendix: Chord symbol conventions

Chord symbol conventions are based on Mehegan [13]. Roman numerals representing scale tone triads or sevenths are written in capitals, **irrespective** of major or minor quality (e.g. I II II IV V etc.). Roman numerals represent triads of the quality normally associated with the degree of the tonality (or modality) prevailing. We call this quality the "default" quality. In the jazz example, Roman numerals indicate scale-tone sevenths rather than triads. The following post-fix symbols are used to annotate Roman chord symbols to override the chord quality as follows ; x - dominant, o - diminished, ø - half diminished, m - minor, M - major. The following post-fix convention is used to alter indicated degrees of the scale; "#3" means default chord quality but with sharpened 3rd, "#7" means default chord quality but with sharpened 7th etc. The following post-fix convention is used to add notes to chords e.g. "+6" means default chord quality with added scale-tone sixth 6th. The prefixes # and b move **all** notes of the otherwise indicated chord a semitone up or down.

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