Visualization of Tonal Harmony for Jazz Lead Sheets

C. Bunks, T. Weyde, A. Slingsby, J. Wood

Department of Computer Science, City, University of London

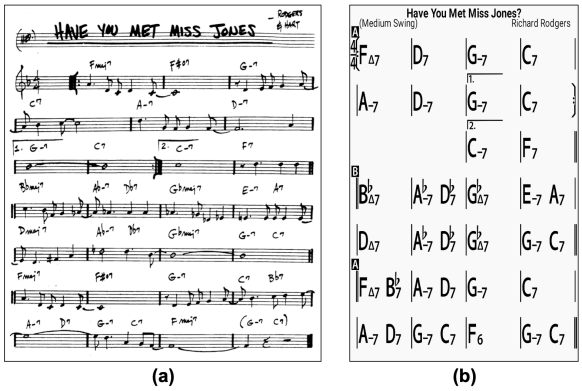
Abstract

Jazz improvisation is the extemporaneous expression of melody, and musicians commonly base their performances on chord progressions given by lead sheets. It is standard practice to commit a progression to memory by analyzing it for common patterns. This paper presents a visualization design intended to help reduce the amount of cognitive work needed to assimilate a song's chords and harmonic patterns. It does this using color, shapes, and glyphs as visual variables to convey meaning about tonal centers, chord functions, and harmonic structure.

1. Introduction

Jazz musicians commonly rely on lead sheets as a source for learning a song's melody and harmony. Figure 1(a) illustrates a lead sheet as published in the Real Book [Ano04]. The song's melody is represented by notes on a staff, and the harmony is represented above it as a sequence of chord symbols. To effectively improvise over a song, the musician must be familiar with its chord progression.

This work is based on the corpus of jazz songs available from the open-source application, *Impro-Visor* [Kel08]. It comes with a collection of 2,612 chord progressions, containing 134,182 chords. Based on this, a jazz standard contains, on average, some 50 chords. To assist in memorization, musicians use a process of analysis to identify common chord patterns.



(a) (b)

Figure 1: *(a) Full lead sheet for the Song* Have You Met Miss Jones?*, (b) Tabular layout of the same chord progression*

The presentation of chord progressions can be made more compact by presenting them in tabular form, removing the staves and notes. An example of this is illustrated in Figure 1(b), a screenshot from the *iReal Pro* application. Even in this representation, the analysis and memorization of the chords and their sequential structure requires significant mental effort, which is evident to musicians, but also increasingly corroborated by psychological research [NJNC08], [Cor16], [MWC18], [GO17]. A reasonable question is whether principles governing good data visualization design can be used to amplify and accelerate the cognition and memorization of harmonic structure in chord progressions.

To answer that question, it is helpful to identify some of the methods musicians use for improvisation. Chord-scale theory [Ter17], [MH13] is a common technique that associates a scale to each chord. The scale contains notes that are harmonically coherent with the chord, and it is said that the scale is associated with a tonal center. For each scale, musicians learn melodic vocabularies such as intervals, arpeggios, and phrases, and use these to improvise over the respective chords. For most instruments, each scale generally requires a different and unique fingering pattern. This means that for each change in tonal center, the musician needs to cognitively 'switch gears' to access and execute the relevant melodic patterns.

Changes in tonal centers can be momentary, lasting for just a single chord, or sustained over multiple chords or measures. A visualization tool that effectively emphasizes the places and types of tonal changes within a chord progression would be useful to musicians preparing for improvisation. It would also be of use to composers and arrangers who study the use of harmonic patterns over collections of songs. As will be seen, changes in tonal centers are also useful for recognizing repeated harmonic structures such *choruses*, *verses*, or *bridges*.

2. Related Work

A good survey of data visualization for music can be found in [LSM21]. A number of authors have focused on the use of visual

variables to enhance the understanding of harmony within a musical score [MPZ18], and the display of hierarchical estimates of tonal center [Sap05].

More relevant to the focus of this paper, is a framework that was specifically designed to facilitate the memorization of chord progressions. Introduced by Cork [Cor21], and later expanded on by Elliott [Ell09], the system, called LEGO Bricks, reduces complexity by segmenting progressions into commonly occurring, short chordal phrases. The result is organized into a tabular format.

Figure 2 illustrates an example of LEGO Brick analysis for the song *Have You Met Miss Jones?*. The figure displays the chords as a sequence of named phrases. The phrases, called "bricks", are connected by named "joins". It is these latter that communicate changes in tonal center, and the name of each join indicates the type of change. The tabular layout helps emphasize the distinct sections of the song. In this figure, the song has an AABA structure, which means that the chord progression is almost the same in the first, second, and fourth rows, whereas the third row, the "bridge" of the song, is different.

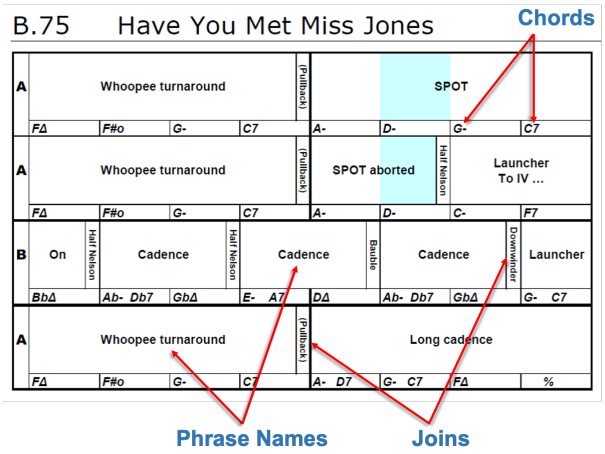


Figure 2: *LEGO Brick analysis of the song* "Have You Met Miss Jones?"

The LEGO Brick method has a few visual characteristics that are useful. Thanks to the layout, the structure is emphasized, and once a familiarity has been developed for the different pattern name types, it requires less effort for memorization. Indeed, the 38 chords for the song in Figure 2 are segmented into just 12 patterns, which, in principle, should be easier to assimilate.

That said, the LEGO Brick method could be improved by more fully leveraging data visualization techniques. The objective of this paper is to describe a new approach that maps harmonic characteristics to visual variables (such as those discussed in [Mun14]) to significantly reduce the cognitive effort needed to understand and memorize harmony.

3. Visual Design

The visual design proposed in this paper uses a tabular layout similar to the LEGO Brick method, but instead of named patterns, sequences of chords that belong to the same tonal center are displayed with the same background color. Figure 3(a) shows the color scheme, where the 12 major keys are organized according to the *Circle of Fifths* (see [Sea21]). The reference key, which for this figure is C major, is always oriented at the 12 o'clock position at the top of the circle. Each step in the clockwise direction adds one sharp to the key, for example, C moves to G major. Each step in the counter-clockwise direction adds one flat to the key, and in this case C moves to B♭ major. The relationship between any key and the reference key can be seen as a distance in either flats or sharps, as shown in the figure.

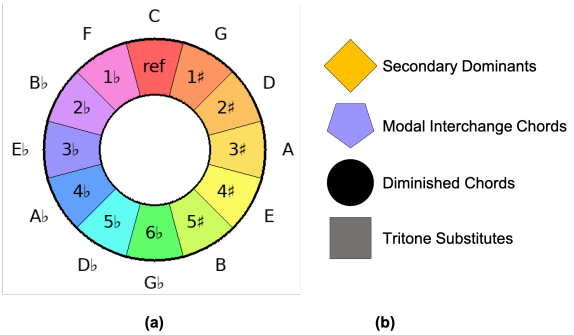


Figure 3: *(a) Background color legend, and (b) Polygon shapes*

At this stage of research, the choice of colors has not been optimized for perceptual or cognitive values, and has simply adopted a coloring scheme as used by some music education publications. Color models are discussed further in section 5.

The reference key is always represented by the red background color, which, when looking at a chord progression, makes it easy to quickly identify all the associated chords. Colors become more yellow when moving to tonal centers in the sharp direction and more blue in the flat direction. The background color hues and values were chosen to achieve qualitatively adequate visual separability while simultaneously maintaining a contrast ratio of at least 7:1 between the background color and superimposed text, as per Web Content Accessibility Guidelines [CCR*08].

The background color does not change for chords that are only momentary departures from an otherwise consistent tonal center. Rather, such a chord is displayed within a polygon whose foreground color is chosen to represent the tonal center that chord belongs to, while the background color retains the same value as its neighbouring chords. There are four classes of these types of chords, and each is represented by a different type of shape, as specified by the list in Figure 3(b).

Figure 4 illustrates an example of the proposed approach (again for the song *Have You Met Miss Jones?*). The 32 measures are arranged as eight cells per row, with each of the four rows representing one of the four sections of the song. The sequence of chords is read from left to right and from top to bottom.

Contiguous sequences of chords belonging to the same tonal center have the same background color, where the color red indicates the song's reference key. As indicated in the figure's legend,

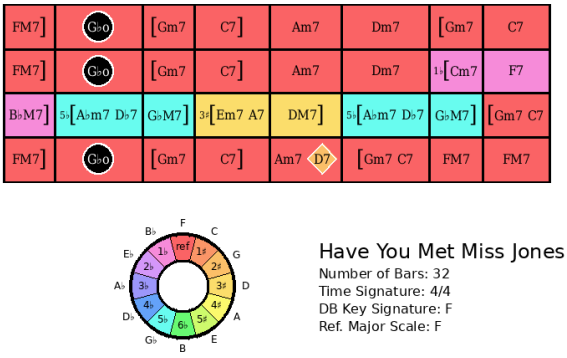


Figure 4: *Visualization for the song* Have You Met Miss Jones?

the reference key for this song is F major. This was algorithmically derived from the chord progression data by tabulating the tonal centers each chord could belong to, and selecting the one that received the highest number of votes.

Most of the cells in Figure 4 have background colors corresponding to the reference key of the song, however four segments have background colors corresponding to other keys. The figure shows these evolving through the colors of violet (B♭ major), cyan (G♭ major), gold (D major), and cyan again before returning to red.

Figure 4 also shows four examples of chords that are momentary departures from the reference key. There is a secondary dominant, D7, found in the fourth row of the table. It is shown in an orange colored diamond-shape, indicating that this chord is from the tonal center of G major, while being used in a sequence of chords from the tonal center of F major.

There are also three instances of the diminished chord, G♭o. Each is shown in a black circle, a color not found in the legend in Figure 3(a). The foreground color for this chord was selected to be black because diminished chords do not belong to any major key.

In addition to the use of color, there are a number of other visual variables in use in Figure 4. Square brackets are used to enclose groups of chords that represent full or partial cadences. A cadence is any sequence of chords moving around the Circle-of-Fifths in the counter-clockwise direction in the form minor, dominant, and major. For example, in Figure 4, the two measures with a yellow background contain the chords Em7, A7, and DM7. From the legend for the figure, it can be seen that the roots of these chords move sequentially in the counter-clockwise direction around the Circle-of-Fifths while having the minor, dominant, and major qualities. Cadences are important in jazz because they are the most common way of establishing a tonal center, and, as they are familiar to musicians, are helpful for memorizing the harmonic structure of a song.

Cadence brackets are preceded by a glyph indicating the cadence's tonal center as situated in the Circle-of-Fifths legend. Figure 4 contains several examples of glyphs. There is the 1♭ that precedes the the cadence in B♭, the 5♭, preceding the cadences in G♭, and the 3♯, preceding the cadence in D.

Some songs have sequences of chords that, as a group, do not express a tonal center. An example of this type of sequence is a chain of dominants. Each dominant chord suggests a tonic it might resolve to, but instead is followed by another dominant. To represent this lack of tonal center, gray is used as the background color for these types of chord phrases. Figure 5 illustrates the visualization of the song *Oleo*, which illustrates an example of a chain of dominants in the third row, the song's "bridge".

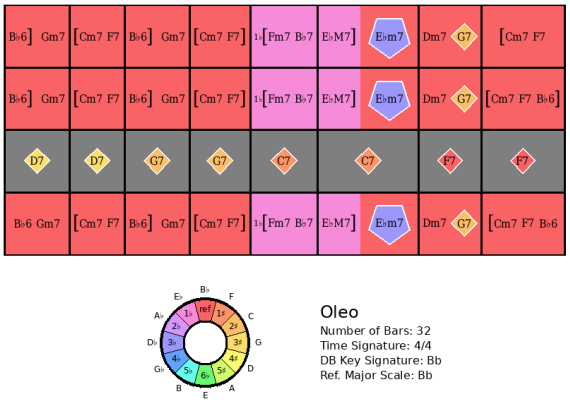


Figure 5: *Visualization for the song* Oleo*, illustrating a chain of dominants with an indeterminate tonal center*

4. Interactive Visual Analysis

In addition to facilitating the memorization of harmony, the visual design described in the previous section is useful for some types of interactive analyses. For example, some songs do not have a standard structure, and the use of visualization can help identify it.

Figure 6(a) illustrates the song *Moonlight in Vermont* using the default layout of eight measures per row. As can be seen from this figure, the song does not seem to have any repeating sections. The rows of the song lack the expected vertical alignment of patterns, and there are two dangling measures in the last row of the table.

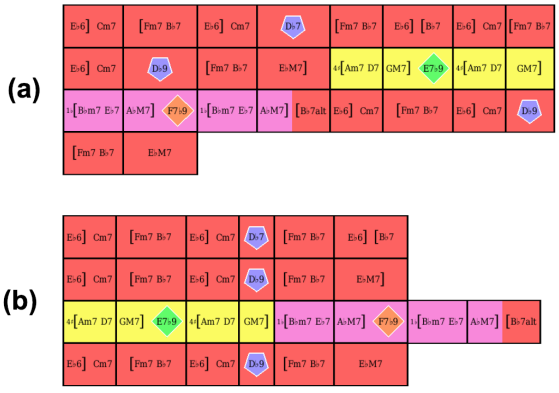


Figure 6: *(a) Visualization for the song* Moonlight In Vermont *using the default layout, and (b) Using a layout of 6 measures in the first, second, and fourth rows, and eight measures in the third row*

A careful examination of Figure 6(a) suggests shortening the first

two rows from eight measures to six to vertically align the pentagonal shapes (as well as many of the other chords). Similarly, the last six chords of the song would also align the position of the pentagonal shape if used in the last row of the song. This leads to a layout of six measures for the first, second, and fourth rows, leaving eight measures for the third row. Figure 6(b), illustrates the resulting structure.

The visualization of harmony can also be useful for identifying a song's reference key. This is helpful when lead sheet data does not provide the song's key, or does so inaccurately. Moreover, it is important for other cases where that information may not be available, such as when the chord progression is automatically extracted from audio using music information retrieval methods [POG*19].

An algorithmic method for determining the reference key from a chord progression was briefly described earlier, however, visualization can be used as an interactive tool to work out a song's key. As an example, examine Figure 7(a), which shows a visualization for the song *Bluesette*. Here, C major is the reference key specified for this song by the database. As can be seen in the figure, however, there are surprisingly few measures with red backgrounds, and there isn't a full cadence in C or even a CM7 chord in the song.

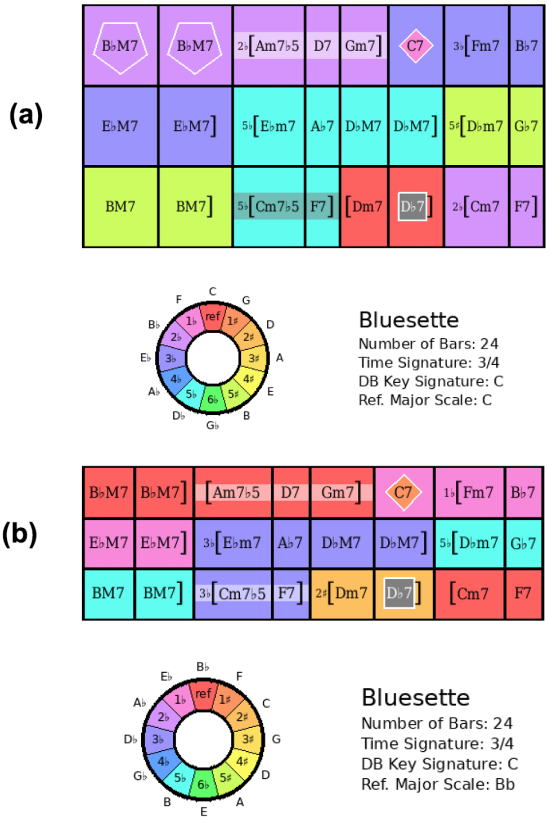


Figure 7: *Visualization for the song* Bluesette *(a) shown in the reference key of C major, and (b) in the key of B♭*

This is an apparent error in the database, and we can use visual feedback to explore alternative reference keys. For example, Figure 7(b) illustrates the song when using the reference key of B♭. Not only are there many more measures with red backgrounds, but there is a complete cadence in B♭ major (wrapping around from the last two measures of the song to the first two).

5. Future Work

Different color designs may suit different types of harmonic analysis, depending on a variety of other contextual factors [PWV*18]. For example, studying harmonic patterns with large jumps around the Circle-of-Fifths might benefit from a color map with smooth, perceptually uniform changes. For example, such a map, based on the CIELab color space ([WVVWVDL08]), is illustrated in Figure 8(a).

Alternatively, the study of harmonic patterns with only small jumps in tonal center might be better served by a map with alternating light and dark colors to help distinguish between adjacent keys. Such a map is illustrated in Figure 8(b).

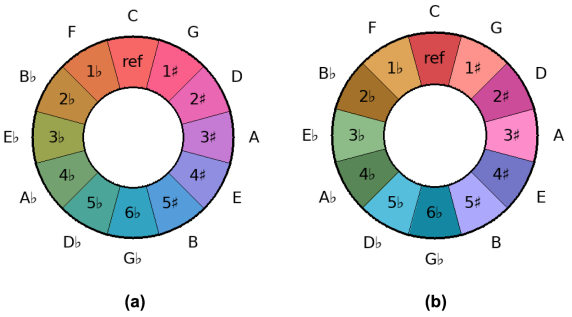


Figure 8: *(a) Perceptually uniform color transitions, and (b) Alternating dark and light transitions*

Making various color schemes available as user options is one of the future developments for this work.

6. Conclusions

The visual design presented in this paper places emphasis on changes in tonal center. The advantage over previous work is that it segments chord progressions in a way that should be helpful to jazz improvisers by capturing how they tend to analyze and mentally organize harmony.

The design differentiates between momentary and sustained changes in tonal harmony, using visual variables such as color, shapes, symbols, and glyphs to make various aspects of the song more cognitively accessible and easier to memorize.

It was demonstrated how the design could be used interactively to help test hypotheses about a song's structure and key, and several examples were presented.

To evaluate the the proposed visual design, the next phase of work requires testing with target users such as jazz musicians, composers, and arrangers. The objectives will be to optimize visual variables and to identify other tasks that might benefit from this approach.

References

[Ano04] ANON.: *The Real Book*. Hal Leonard Corporation, 2004. 1

[CCR*08] CALDWELL B., COOPER M., REID L. G., VANDERHEIDEN G., CHISHOLM W., SLATIN J., WHITE J.: Web content accessibility guidelines (wcag) 2.0. *WWW Consortium (W3C) 290* (2008), 1–34. 2

[Cor16] CORLU M.: *Effects of cognitive load on expressive musical performances*. PhD thesis, Ghent University, 2016. 1

[Cor21] CORK C.: The new guide to harmony with lego bricks: the best way to remember jazz changes. https://dropback.co.uk/, 2021. 2

[Ell09] ELLIOTT J. A.: Insights in jazz (e-book). https://dropback.co.uk/, 2009. 2

[GO17] GRAVES J. E., OXENHAM A. J.: Familiar tonal context improves accuracy of pitch interval perception. *Frontiers in psychology 8* (2017), 1753. 1

[Kel08] KELLER B.: Impro-visor. https://www.cs.hmc.edu/~keller/jazz/improvisor/, 2008. 1

[LSM21] LIMA H. B., SANTOS C. G. D., MEIGUINS B. S.: A survey of music visualization techniques. *ACM Computing Surveys (CSUR) 54*, 7 (2021), 1–29. 1

[MH13] MULHOLLAND J., HOJNACKI T.: *The Berklee Book of jazz harmony*. Hal Leonard Corporation, 2013. 1

[MPZ18] MALANDRINO D., PIROZZI D., ZACCAGNINO R.: Visualization and music harmony: Design, implementation, and evaluation. In *2018 22nd International Conference Information Visualisation (IV)* (2018), IEEE, pp. 498–503. 2

[Mun14] MUNZNER T.: *Visualization analysis and design*. CRC press, 2014. 2

[MWC18] MIKSZA P., WATSON K., CALHOUN I.: The effect of mental practice on melodic jazz improvisation achievement. *Psychomusicology: Music, Mind, and Brain 28*, 1 (2018), 40. 1

[NJNC08] NOICE H., JEFFREY J., NOICE T., CHAFFIN R.: Memorization by a jazz musician: A case study. *Psychology of Music 36*, 1 (2008), 63–79. 1

[POG*19] PAUWELS J., O'HANLON K., GÓMEZ E., SANDLER M., ET AL.: 20 years of automatic chord recognition from audio. In *Proceedings of the 20th ISMIR Conference* (2019). 4

[PWV*18] POLATSEK P., WALDNER M., VIOLA I., KAPEC P., BENESOVA W.: Exploring visual attention and saliency modeling for task-based visual analysis. *Computers & Graphics 72* (2018), 26–38. 4

[Sap05] SAPP C. S.: Visual hierarchical key analysis. *Computers in Entertainment (CIE) 3*, 4 (2005), 1–19. 2

[Sea21] SEALS S.: Circle of fifths explained. *The American Music Teacher 70*, 6 (2021), 52–52. 2

[Ter17] TEREFENKO D.: Chord–scale theory. In *Jazz Theory*. Routledge, 2017, pp. 78–90. 1

[WVVWVDL08] WIJFFELAARS M., VLIEGEN R., VAN WIJK J. J., VAN DER LINDEN E.-J.: Generating color palettes using intuitive parameters. In *Computer Graphics Forum* (2008), vol. 27, Wiley Online Library, pp. 743–750. 4