

A GEOMETRIC ANALYSIS OF THE HARMONIC STRUCTURE OF *IN MY LIFE*

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ABSTRACT. After our book [1] was published, we found a striking example of the importance of the *Tonnetz* for analyzing the harmonic structure of The Beatles' song, *In My Life*. Our *Tonnetz* analysis will illustrate the highly structured geometric logic underlying the numerous chord progressions in the song. Spectrograms provide a way for us to visualize chordal harmonics and their connection with voice leading. We shall also describe the interesting harmonic rhythms of the song's chord progressions. A lot of this harmonic rhythm lends itself well to a geometric description.

1. INTRODUCTION

The Beatles, especially in some classic songs of John Lennon and Paul McCartney, used much more elaborate chord progressions than one finds in typical popular songs. A fine example of this occurs with their song, *In My Life*. For whatever reason, the chord progressions and instrumental melodies found in various sheet musics for Lennon and McCartney songs, such as *In My Life*, are aural transcriptions made by others.¹ This has led to some differences in the various sheet musics, and chord listings, that are available. Our approach to this difficulty is to do an initial analysis on a basic template for the song found in the lead sheet version in [2]. After analyzing its harmonic structure, consisting of a *Tonnetz* analysis of its chord progressions and an examination of its harmonic rhythm, we then look at a computer analysis of the recorded performance of *In My Life* from The Beatles' album *Rubber Soul*. The harmonic structure of this recording involves just a few enhancements of the lead sheet version.

2. HARMONIC STRUCTURE OF THE LEAD SHEET VERSION OF *In My Life*

The lead sheet lays out the song form for *In My Life*, in the key of A. We show this song form here:

$$\text{Verse} \quad \text{Bridge} \quad \text{Verse} \quad \text{Bridge} \quad \text{Interlude} \quad \text{Bridge} \quad \text{Coda} \quad (1)$$

In this section, we shall analyze the harmonic structure of each distinct part—Verse, Bridge, Interlude, and Coda—of this song form.

2.1. Harmonic Structure of Verse. The lead sheet in [2] gives the chord progressions for Verse. These progressions, in terms of *Tonnetz* transformations, are

$$A \xrightarrow{\mathcal{T}} E^7 \xrightarrow{\mathcal{T}} A \xrightarrow{\mathcal{T}} E^7 \xrightarrow{\mathcal{T}} A \xrightarrow{\mathcal{T}} f^\sharp \xrightarrow{\mathcal{T}} A^7 \xrightarrow{\mathcal{T}} D \xrightarrow{\mathcal{T}} d \xrightarrow{\mathcal{T}} A \xrightarrow{\mathcal{T}} f^\sharp \xrightarrow{\mathcal{T}} A^7 \xrightarrow{\mathcal{T}} D \xrightarrow{\mathcal{T}} d \xrightarrow{\mathcal{T}} A \quad (2)$$

In the second instance of Verse, the progression $A \xrightarrow{\mathcal{T}} E^7$ only occurs once. It is worth noting that all of these progressions are single *Tonnetz* transformations. They follow an interesting path through chords on the *Tonnetz*.

In Figure 1, we have plotted the motion of these progressions through the chords on the *Tonnetz*. In these plots, any seventh chords are treated as embellishments of underlying triadic chords. For Verse, the motions of the chord progressions are shown on the left side of Figure 1.

¹We will not speculate whether this is due to the common assertion that Lennon and McCartney could not read music, or due to them simply leaving musical transcriptions of their songs to others.

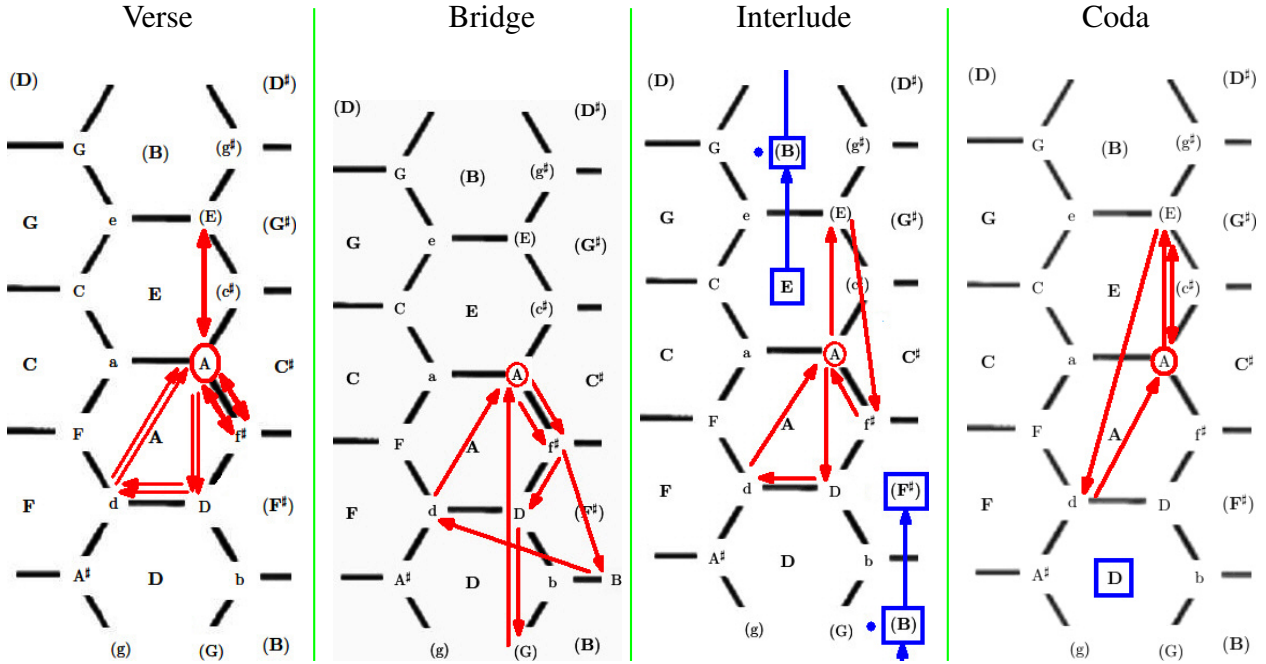


Figure 1. Red arrows show chord progressions on the *Tonnetz* for each of the parts in the song. In Verse, Interlude, and Coda, the circled chord A is the starting and ending chord. In Bridge, the circled chord A is the ending chord of Verse or Interlude, hence $A \xrightarrow{T} f^\sharp$ is the transition to the beginning of Bridge. The chord A is also the ending chord of Bridge. The blue rectangles, and connecting arrows, in Interlude illustrate the movement of pitches that undergirds the double *Tonnetz* transformation $E \xrightarrow{TT} f^\sharp$. The blue dot next to the pitch class B indicates its double position in the *Tonnetz*. The blue rectangle in Coda marks the note D found in both the E^7 chord and the d chord.

The ending progression $A^7 \xrightarrow{T} D \xrightarrow{T} d \xrightarrow{T} A$, corresponding to the triangular path around the pitch class hexagon A is particularly interesting. Here A^7 is functioning as a *secondary dominant* for the chord D, i.e., a dominant for the non-tonic chord D. In roman numerals, this is denoted as V^7/IV . Hence, $V^7/IV \xrightarrow{T} IV$ is the roman numeral version of $A^7 \xrightarrow{T} D$ in the key of A. The transformation $D \xrightarrow{T} d$ is a neo-Riemannian transformation $D \xrightarrow{P} d$ which introduces a *modal mixture*. It is well-known that The Beatles were experimenting with songs in various modes and modal mixtures on the *Rubber Soul* album, and the *Revolver* album that followed it. For example, the Mixolydian mode is used in the song *Norwegian Wood* on *Rubber Soul*. There is also a mode mixture used in *Eleanor Rigby* on *Revolver*, which we discussed in some detail in [1, Example 7.4.6]. For *In My Life*, using the minor chord d—which belongs to the key of a-minor parallel to the key of A-major—provides a mode mixture. The particular progression of $IV \xrightarrow{P} iv$ is often used in music to provide a nice contrast in “color” of these parallel chord types. Within the song *In My Life*, $D \xrightarrow{P} d$ harmonizes well with the chromatic descent in the lyrics from an A note to a natural F note. See Figure 2. Moreover, when the ending chord A is included to form the cadence $D \xrightarrow{P} d \xrightarrow{N} A$, there is a smooth voice leading between the pitches $F^\sharp \rightarrow F^\natural \rightarrow E$ in the respective chords. See again, Figure 2. In roman numerals, this cadence is $IV \rightarrow iv \rightarrow I$, i.e.,

a plagal cadence with modal mixture. We have focused here on the ending cadence, but the other progressions and their motions on the *Tonnetz* are also worth considering, especially in connection with the harmonic rhythm in Verse.

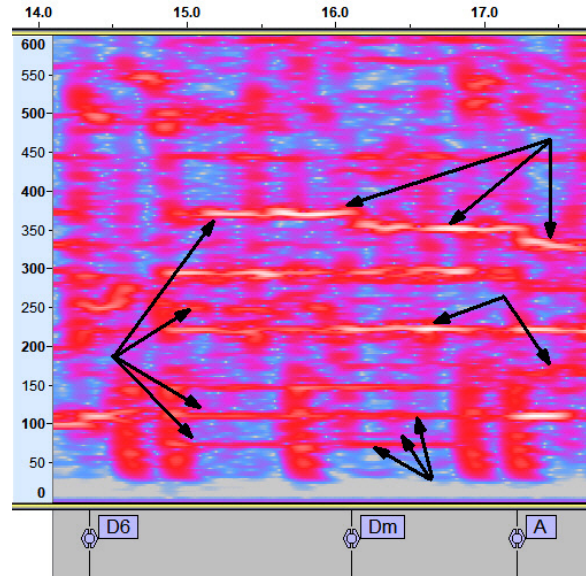


Figure 2. The quadruple arrow points to harmonics for pitches of type D, A, B, F \sharp in ascending order. This is why computer analysis classifies the chord as D 6 (more on this computer analysis in Section 3). In the *Tonnetz* we have plotted this as a D chord, as indicated in the lead sheet. The triple arrow at the bottom points to fundamentals for a d-chord (D $_2$, F $_2$, A $_2$). The double arrow points to fundamentals for the chromatic descent from an A $_3$ note to a natural F $_3$ note, and the fundamental of F $_3$ aligns with a previous second harmonic for the F $_2$ note in the d-chord. The triple arrow at the top points to harmonics for the voice leading F $\sharp \rightarrow F^{\flat} \rightarrow E$.

The harmonic rhythm in Verse closely relates to the structure of the path followed by the chord changes on the *Tonnetz*. This path breaks down into three substructures:

$$\begin{array}{lll}
 A \xrightarrow{\mathcal{T}} E^7 & A \xrightarrow{\mathcal{R}} f^{\sharp} \xrightarrow{\mathcal{R}} A^7 & D \xrightarrow{\mathcal{P}} d \xrightarrow{\mathcal{N}} A \\
 I \xrightarrow{\mathcal{T}} V^7 & I \xrightarrow{\mathcal{R}} vi \xrightarrow{\mathcal{R}} V^7/IV & IV \xrightarrow{\mathcal{P}} iv \xrightarrow{\mathcal{N}} I
 \end{array} \tag{3}$$

Each of these substructures is repeated twice in moving through the *Tonnetz*. The roman numerals are for the chords in the key of A-major, including the notation V 7 /IV that we previously discussed.

The substructures in (3) correspond to three distinct harmonic rhythms. In Figure 3, we show these three distinct harmonic rhythms by plotting them on rhythm clocks of eight hours each, one hour per beat (quarter note), spanning two measures each. The first substructure in (3) has a whole note rhythm (one chord per measure), while the second and third substructures show alternating faster (half-note) rhythm with slower (whole note) rhythm. Furthermore, it is interesting that the second and third clocks in Figure 3 are reflections of each other. The reflections being through a mirror passing through hours 0 and 4, which are the hours for the chord onsets in the first clock.

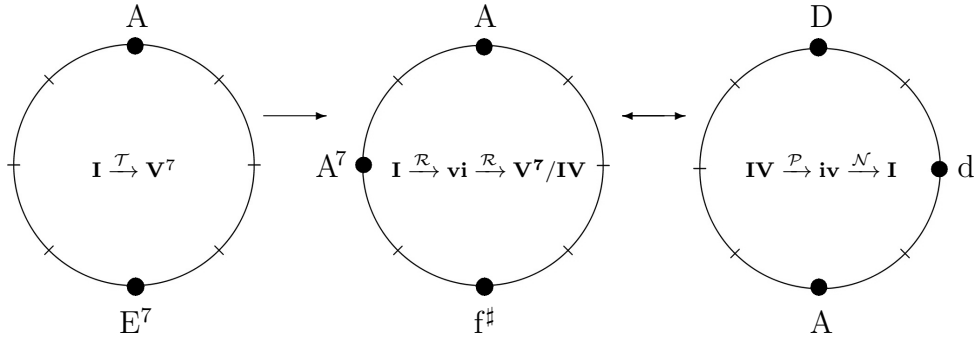


Figure 3. Harmonic rhythm of Verse. The eight hour clocks mark 1 hour per quarter note beat, spanning two measures each. In the first instance of Verse, the clock on the left is cycled through twice. While in the second instance, it is cycled through once. In both instances, the second and third clocks are each cycled through twice in alternation. The arrows mark the change from one clock to the next—one harmonic rhythm to the next—as the music proceeds through Verse, two measures at a time. Within each clock, there is a labeling of its form in terms of roman numerals and types of transformations (either general *Tonnetz* transformation \mathcal{T} , or neo-Riemannian transformation \mathcal{R} , \mathcal{P} , or \mathcal{N}).

2.2. Harmonic Structure of Bridge. The lead sheet in [2] gives the following chord progressions for Bridge:

$$(A \xrightarrow{\mathcal{T}}) f^\sharp \xrightarrow{\mathcal{T}} D \xrightarrow{\mathcal{T}} G \xrightarrow{\mathcal{TT}} A \xrightarrow{\mathcal{T}} f^\sharp \xrightarrow{\mathcal{T}} B^7 \xrightarrow{\mathcal{TT}} d \xrightarrow{\mathcal{T}} A \quad (4)$$

The progression $(A \xrightarrow{\mathcal{T}})$ is not part of Bridge. It indicates the progression from Verse to Bridge, or Interlude to Bridge.

These transformations are graphed on the *Tonnetz* in Figure 1. Most of them are single *Tonnetz* transformations. These single *Tonnetz* transformations either pass across a single hexagon from the set $\{D, F^\sharp, A\}$, corresponding to the chord D, or along an edge between two of these pitch classes corresponding to D. In fact, the D-chord lies in the center of the network of transformations shown for Bridge in the *Tonnetz* diagram. All these geometric facts provide clear evidence for the *tonicization*² of the subdominant chord D in Bridge.

The two exceptions to single *Tonnetz* transformations in (4) are the double *Tonnetz* transformations $G \xrightarrow{\mathcal{TT}} A$ and $B^7 \xrightarrow{\mathcal{TT}} d$. In the chord G, the leading tone G^\sharp has been dropped by a half step to G-natural. This lowering of the leading tone by a half step in order to play a VII-chord was commonly employed in popular music at that time. In which case, the roman numeral form of $G \xrightarrow{\mathcal{TT}} A$ represents a return to the tonic with VII \rightarrow I. The musical practice here is similar to the Renaissance practice of lowering the seventh tone in a major scale in order to avoid tritones. On the left of Figure 4, we show the harmonics for the G-chord. It is interesting that the notes sung by Lennon during the playing of this chord are a descending scale sequence D, C^\sharp , B, A. When the seventh tone for the A-major scale is lowered by a half-step, the resulting scale is A-Mixolydian:

$$A, B, C^\sharp, D, E, F^\sharp, G, A.$$

As shown on the right of Figure 4, Lennon’s lyrical pitch descent from A crosses the second harmonic of the fundamental for the G-chord. If we take this as an implicit sounding of a G-note,

²Tonicization refers to a strong emphasis, or central role, for a scale degree or chord other than the tonic for the key.

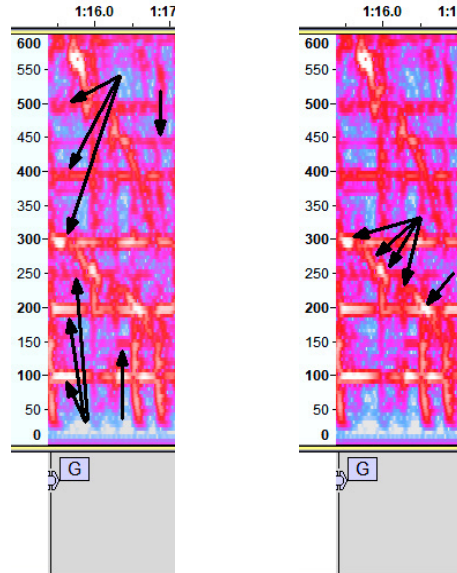


Figure 4. Left: The triple arrow at the bottom indicates harmonics with frequencies corresponding to pitches G_2, G_3, B_3 in ascending order. While the triple arrow at the top indicates harmonics with frequencies corresponding to pitches D_4, G_4, B_5 in ascending order. Consequently, computer analysis classifies the chord being played as a G-chord. The downward pointing arrow points to a harmonic for A_4 which is an overtone for the harmonic for D_4 pointed to by the upward pointing arrow. Right: The quadruple arrow points to fundamentals for the descending sequence of notes D, C^\sharp, B, A . The first fundamental, for the D note, matches the D_4 harmonic in the G-chord. The single arrow points to an implicit G note occurring when Lennon’s pitch descent from A crosses the G_3 harmonic. A video illustrating this implicit note is available at [3].

then the descent is along the A-Mixolydian scale. It is interesting to note in this connection that the note G^\sharp is never used in Bridge, neither in the lyric’s notes nor in the chords. Thus, perhaps we have at least an implicit invocation of the A-Mixolydian mode in Bridge. As for the progression, $B^7 \xrightarrow{TT} d$, when we analyze the recording of *In My Life*, we shall see that $B^7 \xrightarrow{TT} d$ does *not* occur there. Instead, it is replaced by $B \xrightarrow{T} D \xrightarrow{T} d$. Thus, in the recording, even though the chords B and d are not in the key of A , they still play a consonant role in the music due to the *Tonnetz* transformation sequence $f^\sharp \xrightarrow{T} B \xrightarrow{T} D \xrightarrow{T} d$.

There is also a change in harmonic rhythm in Bridge. The harmonic rhythm in [2] is a simple one chord per measure rhythm. This contrasts with the slightly more complex harmonic rhythm of Verse. So we have an interesting change of complexity of the harmonies when Verse changes to Bridge: the chord progressions become more elaborate, while the harmonic rhythm becomes less elaborate. That change of complexity then reverses when Bridge changes back to Verse.

2.3. Harmonic Structure of Interlude. The lead sheet in [2] gives the following chord progressions for Interlude:

$$A \xrightarrow{T} E \xrightarrow{TT} f^\sharp \xrightarrow{T} A^7 \xrightarrow{T} D \xrightarrow{T} d \xrightarrow{T} A \tag{5}$$

All of the transformations in (5) are single *Tonnetz* transformations, except for $E \xrightarrow{TT} f^\sharp$. An interesting feature of this one exception is that, while the chord E is sounding, the notes being

played are a descending series of perfect fourths: E, B, F $^\sharp$. We show the pitch classes for those notes in Figure 1, and it is clear that they lead nicely into the chord f $^\sharp$. It is clear from the *Tonnetz* diagram in Figure 1 that the tonic chord for Interlude is A. This makes sense as Interlude is a substitute for Verse in the song form shown in (1).

The harmonic rhythm in Interlude is mostly half-note. The only exception is that for each of the two passes through Interlude in the lead sheet score, the ending chord A is held for a full measure.

2.4. Harmonic Structure of Coda. There is a brief coda at the end of the song. The lead sheet in [2] gives the following chord progressions for Coda:

$$A \xrightarrow{\mathcal{T}} E^7 \xrightarrow{\mathcal{TT}} d \xrightarrow{\mathcal{T}} A \xrightarrow{\mathcal{T}} E^7 \xrightarrow{\mathcal{T}} A \quad (6)$$

All of these are single *Tonnetz* transformations, with one exception: $E^7 \xrightarrow{\mathcal{TT}} d$. This is a surprising progression, as the dominant seventh chord E^7 would typically anticipate the tonic chord A. However, the progression to the subdominant minor chord d, used frequently throughout the song—along with Lennon singing a chromatic descending sequence of pitches C $^\sharp$, B, A—provides a nice unexpected twist to the music in this final part.

The harmonic rhythm for the Coda is whole note throughout. It thus provides a slowing down from the half-note harmonic rhythm at the end of the last Bridge.

2.5. Summary. The lead sheet provides a foundation for understanding the fascinating harmonic structure of *In My Life*. We have seen that the *Tonnetz* provides a powerful tool for understanding the geometric logic underlying the chord progressions in the song. A geometric analysis also sheds light on some of its harmonic rhythm.

3. HARMONIC STRUCTURE OF THE RECORDING OF *In My Life*

The recording of *In My Life* for the most part follows the structure given in the lead sheet in [2]. There are some interesting differences, however, which serve to enhance the harmonic structure in the recorded version.

To transcribe the chords in the recorded version of *In My Life*, we used a computer program called CHORDINO. CHORDINO is available from the link given in [4]. We used CHORDINO as a plug-in to the free audio software AUDACITY. To analyze the recording of *In My Life*, we first converted the stereo file from the *Rubber Soul* CD to mono.³ We used the default settings in CHORDINO, with one modification: Following the advice given in [4] for analyzing popular music, we set the spectral roll-off parameter to 1.0. CHORDINO identifies chords by detecting the harmonics for the notes composing the chords. In Figures 2 and 4 you can gain some idea how identifying the sets of harmonics in the sound can be used to identify the individual notes in a chord, and thus identify the chords themselves.

The chordal analysis given by CHORDINO differed from the lead sheet in just a few places. The differences occurred in the Verse and Bridge parts. Here we will discuss the differences for the first instance of Verse and the second instance of Bridge. That will capture the essence of the differences between the lead sheet version and the recording.

³We found that the lossless *.wav form of the recording did not produce good results, as CHORDINO could not reliably reproduce known chords from the lead sheet. However, when we analyzed *.m4a (highest quality of 320 kbs) and *.mp3 (standard quality 128 kbs) formats, CHORDINO reproduced the chords found in the lead sheet and gave the same results for additional chords, and these are the chords we report here.

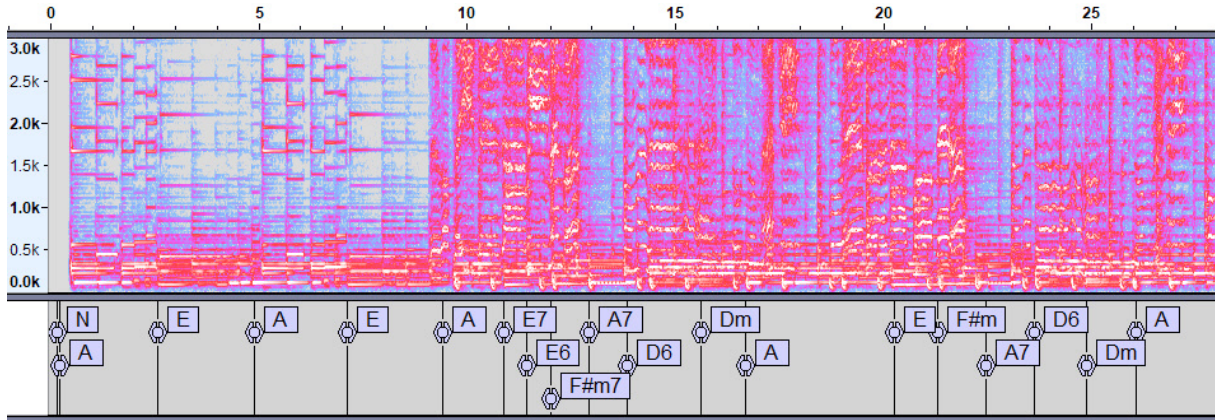


Figure 5. CHORDINO analysis of chords in first instance of Verse. The notation N indicates that no identifiable chord is played at the start, so the first chord is A.

3.1. Harmonic Structure of Verse. In Figure 5, we show the CHORDINO analysis of the chords in the first instance of Verse. This analysis gives us the following progressions:

$$\begin{aligned}
 & A \xrightarrow{T} E \xrightarrow{T} A \xrightarrow{T} E \xrightarrow{T} A \xrightarrow{T} E \xrightarrow{TT} f^\# \xrightarrow{T} A \xrightarrow{T} D \\
 & \xrightarrow{T} d \xrightarrow{T} A \xrightarrow{T} E \xrightarrow{TT} f^\# \xrightarrow{T} A \xrightarrow{T} D \xrightarrow{T} d \xrightarrow{T} A
 \end{aligned} \tag{7}$$

where we have replaced some chords by their underlying triads—viewing E^7, E^6 as embellishments of the chord E, $f^{\#7}$ as an embellishment of the chord $f^\#$, D^6 as an embellishment of the chord D, and A^7 as an embellishment of the chord A.

Unlike in the lead sheet Verse, there are a couple of double *Tonnetz* transformations in addition to the many single *Tonnetz* transformations. The motion of these chord progressions on the *Tonnetz* is shown on the left of Figure 6. The overall pattern is quite similar to the one shown for Verse in Figure 1. The one difference is the two double *Tonnetz* transformations of type $E \xrightarrow{TT} f^\#$. These double *Tonnetz* transformations enhance the pattern from the lead sheet. To be more precise, in the key of A, they are both instances of the deceptive progression: $V \xrightarrow{T} vi$, which adds some variety to the harmony. Moreover, the occurrence of the notes $C^\#$ in Lennon’s lyrics immediately preceding the chords $f^\#$ makes the transformations $E \xrightarrow{TT} f^\#$ more sonorous.

The sequence in (7) breaks up into four distinct substructures:

$$A \xrightarrow{T} E \quad A \xrightarrow{T} E \xrightarrow{TT} f^\# \xrightarrow{\mathcal{R}} A \quad A \xrightarrow{T} D \xrightarrow{\mathcal{P}} d \quad A \xrightarrow{T} E \xrightarrow{TT} f^\# \tag{8}$$

which differ from the three substructures in the lead sheet Verse given in (3). Likewise, there is a different harmonic rhythm corresponding to these substructures. This harmonic rhythm is shown in Figure 7.

Thus, in the recorded version of *In My Life* there is a slightly more sophisticated sequence of chord progressions (including enhanced voice leading), as well as slightly more sophisticated harmonic rhythm. This increased sophistication also occurs in the Bridge part.

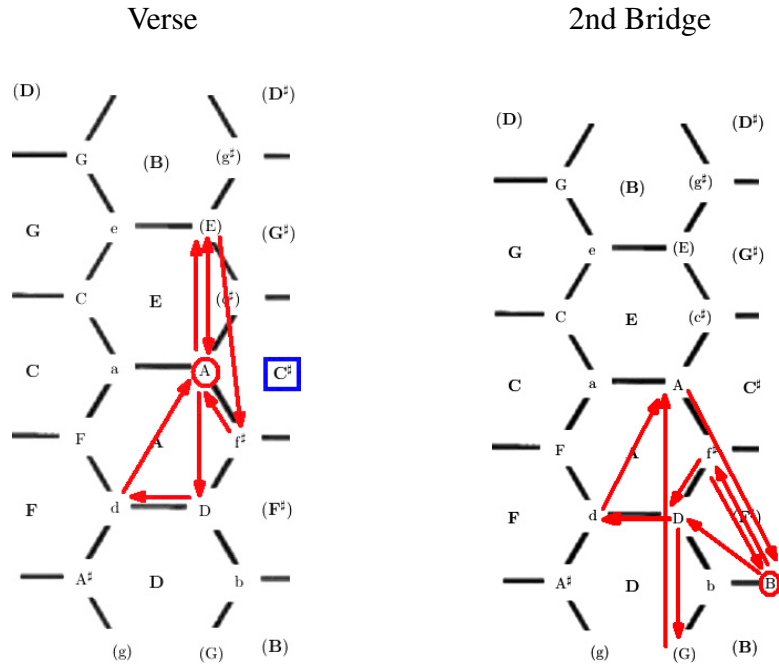


Figure 6. Movement of chords on the *Tonnetz* for the first instance of Verse and the second instance of Bridge. The blue rectangle in the Verse diagram marks the note C^\sharp that immediately precedes the chord f^\sharp in the progression $E \xrightarrow{\mathcal{T}\mathcal{T}} f^\sharp$.

3.2. Harmonic Structure of Bridge. The second instance of Bridge most clearly illustrates the enhanced harmonic structure of the recorded version of *In My Life*. In Figure 8, we show the CHORDINO analysis of the chords in the second instance of Bridge. The chord progressions identified by CHORDINO are the following:

$$B \xrightarrow{\mathcal{T}} f^\sharp \xrightarrow{\mathcal{T}} D \xrightarrow{\mathcal{T}} G \xrightarrow{\mathcal{T}\mathcal{T}} A \xrightarrow{\mathcal{T}\mathcal{T}} B \xrightarrow{\mathcal{T}} f^\sharp \xrightarrow{\mathcal{T}} B \xrightarrow{\mathcal{T}} D \xrightarrow{\mathcal{T}} d \xrightarrow{\mathcal{T}} A \quad (9)$$

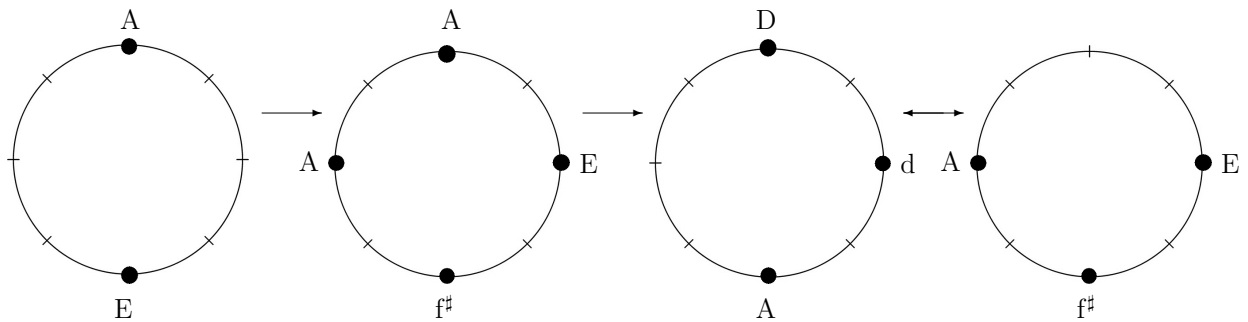


Figure 7. Harmonic rhythm of first version of Verse in the recording of *In My Life*. The meaning of the hours is the same as for the clocks in Figure 3. The first clock is cycled through twice. The second clock is cycled through once. The third and fourth clocks are cycled through in alternation (third clock, fourth clock, third clock).

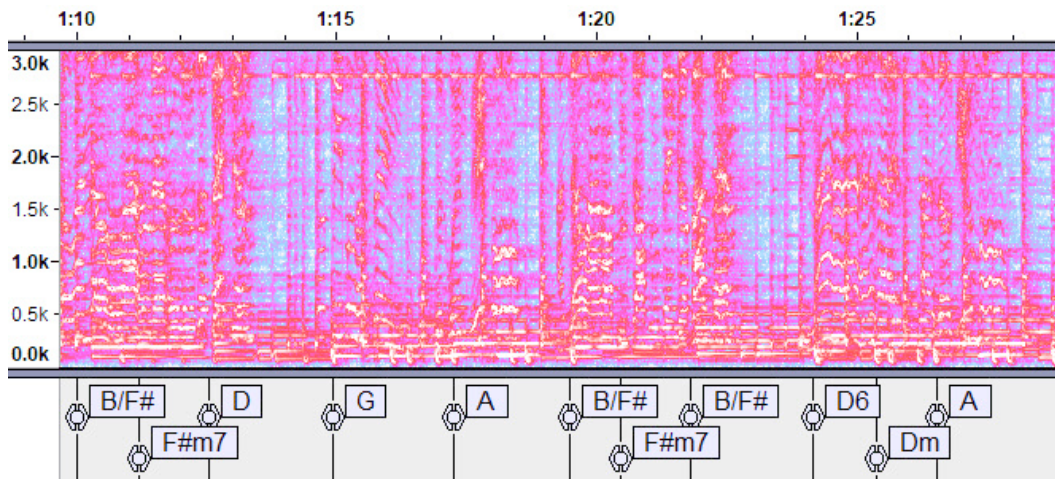


Figure 8. CHORDINO analysis of chords in second version of Bridge.

where we have written the chord B/F^\sharp as simply B and written a couple of other chords by their underlying triads—viewing $f^\sharp7$ as an embellishment of the chord f^\sharp , and D^6 as an embellishment of the chord D .

As with the lead sheet version, most of these transformations are single *Tonnetz* transformations. The pattern of the progressions on the *Tonnetz* is shown on the right of Figure 6. As with Verse, this second version of Bridge is quite similar to its lead sheet version, but with some interesting enhancements. For one thing, the tonicization of the subdominant D chord is more clearly emphasized as the central chord in the diagram in Figure 6. For another, the chromatic chord B receives much more emphasis. This enhanced emphasis includes the use of the chromatic mediant transformation $B \xrightarrow{T} D$.

The harmonic rhythm in the recorded version is also more interesting than in the lead sheet. In the recorded version, if we look at the length of separation between successive chords shown in Figure 8, we can see that this rhythm consists of interspersing half-note rhythms (such as B/F^\sharp to $f^\sharp7$) and whole note rhythms (such as D to G) with one slightly different splitting of one measure (B/F^\sharp to $f^\sharp7$ to B/F^\sharp). This is a much more nuanced harmonic rhythm than in the lead sheet.

3.3. Interlude and Coda. The Interlude and Coda of the recorded version are identical in their harmonic structure to the lead sheet version. This is understandable as the Interlude was composed for solo piano (played by George Martin and then sped up to sound like a harpsichord). Consequently, the lead sheet is a faithful transcription of the music (undoubtedly played by Martin from his own sheet music). The Coda is so brief that it probably allowed no room for any elaborations by The Beatles during the recording process.

3.4. Summary. The recorded version of *In My Life* is an enhancement of the lead sheet version. We have seen how the recorded version builds upon the underlying logic of the lead sheet version. It does this by an increased emphasis on chromaticism, slightly more complex chord progressions, and slightly more complex harmonic rhythm.

4. CONCLUSION

In this paper we have used geometric methods to analyze the harmonic progressions and the harmonic rhythms in the song, *In My Life*. The *Tonnetz* provided a powerful geometric tool for understanding the logic of the song's harmony. Spectrograms provided a useful tool for visualizing the interplay of harmonics in voice leading. Clock diagrams were also quite useful for analyzing the details of the changing harmonic rhythms in the song. We have endeavored to show as well that these two geometric approaches were closely linked in the Verse parts of *In My Life*. Our analysis has revealed many of the details of how The Beatles elaborated on basic harmonic patterns to create progressions more elaborate than typical ones used in rock music at that time.

REFERENCES

- [1] J.S. Walker and G.W. Don. (2020). *Mathematics and Music: Composition, Perception, and Performance. 2nd Edition*. CRC Press.
- [2] Lead sheet for *In My Life* is available here:
<https://www.musicnotes.com/sheetmusic/mtd.asp?ppn=MN0053995>
- [3] Video of implicit G-note is available here:
<https://tinyurl.com/ImplicitG>
- [4] CHORDINO is available here:
<http://www.isophonics.net/npls-chroma>

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